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This study compared the effects of previous task training/experience and alternative methods for presenting procedural instructions on job task performance. Six computer-based methods were examined by having oscilloscope operators perform four equipment-related tasks. The presentation methods were text-only, audio-only, text-audio, text-graphics, audio-graphics, and text-audio-graphics. Results showed that regardless of the subjects' prior training and experience in operating oscilloscopes, the most efficient and effective task performances were obtained through a combination of audio and graphic presentations, an effect which can be further enhanced by the addition of redundant textual instructions. The practical applications and theoretical implications of these findings are discussed.

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Comparing Alternative Computer-based Methods for Presenting Job Task Instructions

NPRDC TR 88-6 February 1988

COMPARING ALTERNATIVE COMPUTER-BASED METHODS FOR PRESENTING JOB TASK INSTRUCTIONS

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Approved for public release;
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FOREWORD

This effort was conducted in support of the Joint Service Manpower and Training Development Program sponsored by the Office of the Undersecretary of Defense, Engineering and Logistics Support (OUSD/E&LS), Work Unit Code 99000N: Personal Electronic Aid for Maintenance (PEAM). The monitoring organization was the U.S. Army Research Institute, PERI-MB. The work described in this report provides definitive comparisons between alternative computer-based presentation methods based on the PEAM technical information delivery concept.

Appreciation is expressed to the Commanding Officer, Service School Command, Naval Training Center, San Diego, and the Commanding Officer, Recruit Training Command, Naval Training Center, San Diego, for providing the test subjects in the present effort.

The author also wishes to thank FC1 Carl Huttner, formerly assigned to Code 522, Navy Personnel Research and Development Center (NAVPERSRANDCEN), who programmed the computer-based instructions, graphics, and automated data recording procedures used in this effort.

This report is intended for use by military and civilian personnel concerned with designing or developing automated technical information delivery systems.

Comments regarding this report are welcome. Point of contact at NAVPERSRANDCEN is Mr. William A. Nugent, Human Factors Department, (619) 553-8005 or AUTOVON 553-8005.

B. E. BACON
Captain, U.S. Navy
Commanding Officer

JAMES McMICHAEL
Technical Director

SUMMARY

Problem

An impressive number of studies have been reported in the literature comparing the effects of various audiovisual media in presenting academic- or job-related instructional materials. While that literature has reported consistent findings for certain variables and performance settings, the overall generality of findings is poor due to incomplete specification of relevant treatment comparisons and/or inadequate experimental controls. The need for more systematic research in this area is particularly acute at present given rapid advances in computer technology--technology which has now made possible the combining of animated graphics and speech-output features with computer-presented text.

Objectives

The objectives of this effort were to (1) compare the relative efficiency and effectiveness of six computer-based methods for presenting job task instructions, (2) assess differences in subjects' performance based on their prior training/experience in performing the tasks sampled, (3) determine any interaction effects between the foregoing factors, and (4) test certain predictions suggested by Paivio's dual-coding theory of information processing in an applied setting. The theory posits that information represented by both verbal and image codes is more powerful than that represented by either coding system alone.

Method

Two subject groups were formed: one consisted of 90 Navy enlisted personnel who had prior training and experience in operating oscilloscopes; the other, of 90 Navy recruits who had no such prior training or experience. Subjects in each group were randomly assigned to one of six instructional presentation conditions: text-only, audio-only, text-audio, text-graphics, audio-graphics, and text-audio-graphics, resulting in 15 subjects per condition. Each subject performed the following oscilloscope operator tasks sequentially: (1) initial setup and adjustments, (2) probe calibration, (3) amplitude measurement, and (4) frequency measurement. Five performance measures were obtained for each task: time-to-completion, passing or failing performance scores, and separate frequency counts for task steps that were repeated, performed incorrectly, or performed out of sequence.

A 2 x 6 between-subjects, multiple analysis of variance (MANOVA) served as the model for testing the following experimental hypotheses: (1) trained and experienced oscilloscope operators will demonstrate better task performance than untrained, inexperienced ones; (2) for both groups, subjects assigned to presentation methods that include graphics will demonstrate better task performance than subjects assigned to methods that exclude graphics (3) for both groups, no differences in task performance will be found between subjects assigned to the text-audio method and subjects assigned to the text-only and audio-only methods; (4) for both groups, no difference in task performance will be found between subjects assigned to the text-audio-graphics method and subjects assigned to the text-graphics and audio-graphics methods.

Results

Significant main effects were obtained for the experience and presentation method variables, but the interaction between them was nonsignificant. As predicted, the performance of the experienced subjects was significantly better than that of the

inexperienced ones, with the most pronounced differences occurring on the probe and amplitude tasks. Performance of subjects using methods that included graphics information was significantly better than that of subjects whose methods excluded graphics for all but the frequency task. These findings were interpreted as providing substantial support for the second experimental hypothesis. Contrary to the third and fourth hypotheses, subjects assigned to the text-only and text-graphics methods repeated a significantly higher number of steps on all tasks and had significantly higher failure rates on certain tasks than subjects whose methods included audio instructions.

Conclusions and Implications

The data suggest that more efficient and effective performance may result when highly proceduralized job task instructions are presented in a combined audio-graphics format. This effect can be enhanced further through the inclusion of redundant task instructions in textual form. It is important to note, however, that the foregoing methods had their greatest impact early in the performance of consecutively administered job task procedures; that is, when all subjects were becoming familiar with the location and function of particular oscilloscope controls. Moreover, the results lend support to Paivio's dual-coding theory of information processing in an applied setting.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

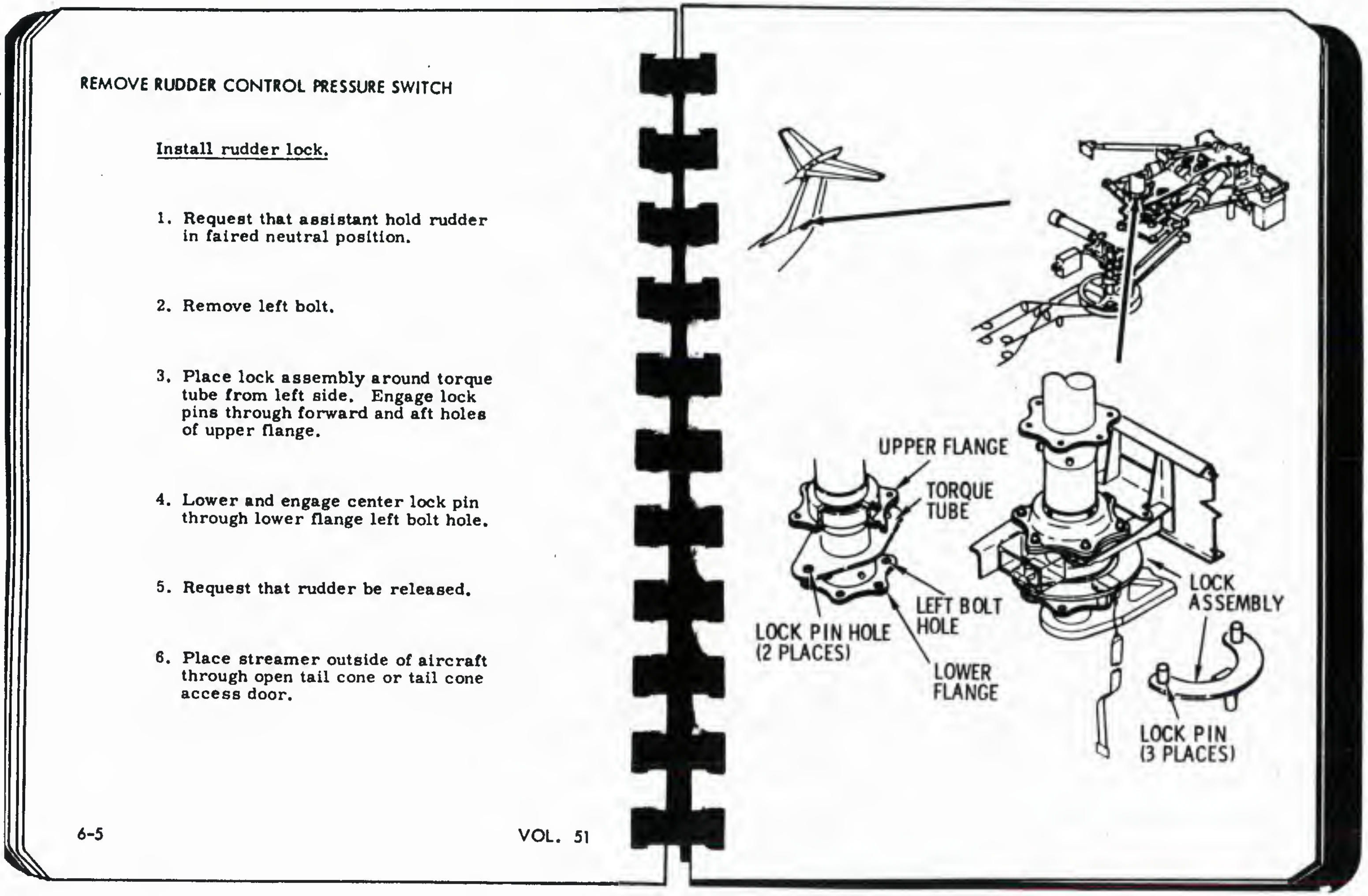
Problem and Background

People in many sectors of working life increasingly depend on sophisticated equipment and detailed procedures to assist them in performing their jobs. The users of such equipment and procedures must often rely on information of a technical nature, ranging from simple, step-by-step instructions to complex concepts involving system interrelationships and theory of operation. In this connection, the writers of job-related technical information are continually faced with the problem of selecting among various methods the best one for organizing, formatting, and ultimately presenting this type of information to users. All too often, choices are made from among available methods, with little or no knowledge of the comprehensibility or general usefulness of the resultant information, particularly from the user's perspective.

One method for dealing effectively with problems of organizing and formatting job-related technical information has involved the development of prescriptive manuals, commonly referred to as job performance aids (JPAs). A primary focus of this method involves modeling the job activities the user is expected to perform, then using the model to predict the user's information needs and how the technical information should be organized to meet those needs. The JPA method also takes the user's cognitive skills into consideration through the use of specific guidelines that prescribe the formatting of text and instructions. Besides containing standard verb lists for describing job task steps in discrete, action-oriented terms, these guidelines provide rules for formatting task steps in a checklist fashion. Some rules limit the number of words, sentences, and steps per page to facilitate rapid scanning and retention of the information. Other rules often specify the pairing of task steps with drawings that show the location of parts, and/or the physical actions needed to perform each step. An example of a typical JPA is given in Figure 1.

Research on JPAs conducted since the early 1950's has been reviewed extensively by Booher (1978), Foley and Camm (1972), Rowan (1973), and Smillie (1985). The major conclusions that can be drawn from these reviews are that the use of JPAs not only improves the clarity of the technical information needed to perform job tasks, but also reduces the requirement for extensive training and experience of the user. For example, Foley and Camm (1972) reported that inexperienced Navy maintenance technicians who used JPAs performed the same job tasks as well as more experienced technicians who did them routinely, with or without the use of conventional technical manuals. Even highly trained and experienced job incumbents made fewer errors when using JPAs under controlled test conditions (Foley, 1973).

While the findings from these and other studies have shown JPAs to be effective in improving job task performance, several problems have inhibited their widespread use in civilian and military work settings. For one thing, since JPAs are intended primarily as supplements to conventional technical manuals, they add to the steady proliferation of technical information (Duffy, 1985; Palmer & Stembler, 1983; Sulit & Fuller, 1976). For another, the development of JPAs frequently requires substantial investment both in terms of front-end analyses and subsequent verification of the information. These factors result in JPAs that are equally as, and in some cases more, costly to design, produce, and update as conventional technical manuals.



REMOVE RUDDER CONTROL PRESSURE SWITCH

Install rudder lock.

1. Request that assistant hold rudder in faired neutral position.

2. Remove left bolt.

3. Place lock assembly around torque tube from left side. Engage lock pins through forward and aft holes of upper flange.

4. Lower and engage center lock pin through lower flange left bolt hole.

5. Request that rudder be released.

6. Place streamer outside of aircraft through open tail cone or tail cone access door.

6-5 VOL. 51

Figure 1. An example of a JPA (from Goff, Schlesinger, & Parlog, 1969).

Recognizing these problems and tradeoffs, civilian and military planners have devoted considerable attention in recent years to the development and use of new methods for presenting job-related technical information, especially the use of portable "stand-alone" microcomputers. In addition to the potential that such devices offer for storing and providing rapid access to large amounts of technical information, recent advances in computer technology have made possible the inclusion of a variety of enhancements, such as animated graphics and text-to-speech output features. To date, however, there is a paucity of research in the literature demonstrating benefits to the user of automating the delivery of technical information. Moreover, there have been no definitive comparisons reported in the literature regarding current options for presenting job-related technical information via computer.

Objectives

The present study was designed to (1) compare the relative efficiency and effectiveness of six alternative computer-based methods for presenting job task instructions, (2) assess differences in subjects' performance based on their prior task training and experience, (3) determine any interaction effects between the foregoing factors, and (4) test certain predictions of a dual-coding theory of information processing in an applied research setting.

REVIEW OF THE LITERATURE

A detailed literature review was conducted to gain a better understanding of the effects of audio and visual presentations on human learning and performance. The basic source materials used in the literature survey included standard psychological, educational, and audiovisual communications journals; technical reports from civilian and military research centers; and bibliographic searches of computerized data banks of the National Technical Information Service (NTIS) and Educational Research Information Center (ERIC). This search was aided greatly by several reviews and annotated bibliographies of the audiovisual communications literature, including those of Chalupsky and Kopf (1967), Day and Beach (1950), Hartman (1961b), Levie and Dickie (1973), and Sticht, Beck, Hauke, Kleiman, and James (1974).

The literature review focused on studies that compared the effectiveness of audio and visual media in presenting academic or job-related instructional materials. Theories and models concerned with human communication and information processing were considered only insofar as they provided a basis for understanding, explaining, or measuring the effects of various audiovisual presentations from both basic and applied research perspectives. The publications were divided into the following content areas: (1) studies relevant to academic instructional materials and settings, (2) studies concerned with job-related instructional materials in applied settings, and (3) publications dealing with model or theory development. The studies in the first two content areas were subdivided further to specify the number and type of audiovisual presentation methods compared, while the third content area classified publications within the framework of two theoretical perspectives.

Studies in Academic Settings

For the most part, studies in this area were restricted to those that compared the effects of various audio and visual presentations on the learning of meaningful, connected discourse (e.g., sentences, passages, or lecture-type materials), and those that used young

adults, ranging from high school students to military enlistees, as test subjects. The former limitation was imposed primarily because of the close relationship that such materials have to traditional methods for presenting job-related information; the latter, to provide a basis for extending methodologies and/or generalizing the findings from these studies to the present research.

Comparisons of Single-channel Presentations

The literature presents some conflicting results regarding the use of text-only, audio-only, or pictures-only as separate channels for communicating instructional materials. Levie and Dickie (1973), for example, cite six studies that showed that reading was superior to listening for high school and college students when learning was tested either by immediate or by longer-term recall. Similar findings were obtained in nine studies reviewed by Hartman (1961b), in which text was found to be superior to audio for the retention of meaningful prose among adult subjects.

Contrary results for the same channel comparisons involving the retention of prose materials among college students were reported by Worcester (1925), Greene (1934), and Goldstein (1940). Goldstein's study was the only one reviewed in which reading rate was paced line-by-line to match the rate of presenting the same materials aurally. With this control of reading rate, listening comprehension exceeded reading comprehension.

Several publications reported no reliable differences between text and audio presentations. These included studies that dealt with college-level prose material (Nasser & McEwen, 1976); remedial mathematics instruction for enlisted Navy personnel (Main, 1974); and a set of studies reviewed by Sticht, Beck, Hauke, Kleiman, and James (1974) in which listening and reading comprehension skills were generally found to be equivalent. Similarly, near equivalence in reading and listening comprehension skills was confirmed in subsequent research by Sticht, Hooke, and Caylor (1982) for young adults whose reading abilities varied from the 2nd through 11th grade levels. These findings were based on data from more than 2,000 prospective enlistees for military service.

Conflicting findings have also been reported in the literature when comparing learning from pictures with that from text or audio presentations. Of 14 studies cited by Hartman (1961b), 5 found an advantage for the pictorial channel over the text; 6 found an advantage for the pictorial channel over audio; and 3 found no differences. More recently, Baggett (1979) compared college students' recall of a story in text and in a silent film version and found no difference between these presentation modes. Gropper (1966) and Levin (1973) also found no significant differences between learning from pictorial and textual materials.

Comparisons of Dual-channel Presentations

These studies dealt with comparisons of dual channel presentations with one another or with single channel presentations. For this review, dual channel was defined as the simultaneous presentation of the same material by combining two separate information channels (e.g., text and audio, text and pictures, audio and pictures). As noted by Hartman (1961a), there are four possible ways information can be presented using two channels: it can be redundant, related, unrelated, or contradictory. Since the most common situations encountered in educational settings are those involving the simultaneous presentation of redundant or related information, studies involving the other variations were not considered.

In a review by Day and Beach (1950), nine studies were cited in which a combined text and audio presentation of material led to more efficient comprehension than the presentation of either text or audio alone. Webb and Wallon (1956) and Hartman (1961a) concluded from similar results that a simultaneous text-audio presentation is more effective than either text or audio alone, provided that the information presented in the two channels is redundant.

Exceptions to the foregoing have been reported in other studies, however. Nasser and McEwen (1976) found that a combined text-audio format was superior to audio alone, but that the dual presentation had no advantage over a text-only format when dealing with college-level prose material. Main (1974) reported that supplementing printed texts with verbatim audio recordings failed to improve the effectiveness of a Navy remedial mathematics course. A possible reason offered for the failure of the audio supplement to improve test performance in this study was that the printed materials intentionally provided instruction with low verbal content.

Thus, equivocal findings have been reported for comparisons between combined text and audio channels and single channel presentations. However, numerous studies have demonstrated that the addition of pictures to text or audio generally increases learning. Moreover, the positive effect of pictures has been empirically validated across a diverse set of subject groups and instructional materials. Rasco, Tennyson, and Boutwell (1975) found that pictorial additions facilitated high school students' comprehension of mathematical concepts. Dwyer (1967, 1968) discovered that the addition of pictures improved the effectiveness of physiology instruction, whether it was presented to high school students in texts or to college students in lectures. Sellman (1972) reported that the effectiveness of an Air Force text on fire fighting was improved by adding pictorial presentations. Still other studies have shown that pictures can serve as advance organizers for instructional materials (e.g., Bransford & Johnson, 1972; Brody & Legenza, 1980; Snowman & Cunningham, 1975).

In comparing two-channel presentations with one another, several studies have found an advantage for pictorial over printed augmentation of orally presented information (Peng & Levin, 1979; Rowher & Harris, 1975; Rowher & Matz, 1975). It should be noted, however, that these findings were based on relatively simple prose materials administered to elementary school children. Similar comparisons involving more complex instructional materials administered to Navy trainees (Main & Griffiths, 1977) found no difference between combined text-pictorial and audio-pictorial presentations.

Comparisons of Multiple-channel Presentations

The three studies reviewed in this subcategory compared the combination of text, audio, and pictorial information channels with the same three channels used separately or in various pairs. In a study by Hartman (1961a), groups of college students were given a perceptual discrimination task using one of the foregoing presentation conditions. His results showed the text-audio combination to be the most consistently effective of the seven conditions tested. Studies conducted by Nugent[1] (1982) and Rowher and Harris (1975) also compared these same treatment conditions using elementary school children as subjects. Unlike Hartman (1961a), these authors found no advantage for the combined text and audio condition over any of the single-channel presentations. Their results did, however, indicate that the combination of pictures with text or audio generally maximized learning. A consistent finding in all three studies was that performance in the combined text, audio, and pictorial condition was no better than that in various dual-channel presentations.

[1] No relation to the author of this report.

Studies in Applied Settings

The studies reviewed in this content area compared the effects of various audio and visual presentation methods in providing the information needed to perform actual or simulated job tasks. These studies also included a diverse set of subjects, ranging from college students to factory workers.

Comparisons of Single-channel Presentations

The two studies included in this area examined the effects of presenting instructional materials in text and pictorial form. In one study, Booher (1975) compared the speed and accuracy with which Navy enlisted personnel performed three different types of simulated job tasks using the above presentation methods. On the average, subjects in the pictorial-only condition completed all tasks in about one-third less time than subjects in the text-only condition. This significant increase in speed was at the expense of accuracy, however, in that subjects assigned to the text-only condition made significantly fewer errors than subjects in the pictorial-only condition.

Contrary findings on the accuracy of task performance using these same two presentation methods were reported by Stone and Glock (1981). In this study groups of college students received instructions for assembling a scale-model loading cart. Results showed no difference in the total number of errors made between groups of subjects who viewed only text and those who viewed only illustrations. When analyses were performed on specific types of errors, however, it was found that subjects in the pictorial-only condition made significantly fewer errors of orientation (i.e., parts of the model attached at the proper place but not properly oriented in space) than subjects in the text-only condition. Time measures for task performance were not obtained in this study.

Comparisons of Dual-channel Presentations

The foregoing studies also included comparisons of various dual-channel presentations involving the combination of text and pictorial instructions. The Stone and Glock (1981) study showed that subjects in the combined text-pictorial condition made significantly fewer errors in the assembly task than subjects in either the text-only or pictorial-only condition. Further, subjects in the text-pictorial condition made significantly fewer errors in orientation of parts than text-only subjects, but no fewer errors than pictorial-only subjects.

In addition to the single-channel presentation methods described above, Booher's (1975) study also included four dual-channel conditions. Two of these consisted of predominantly textual formats, supplemented with either related or redundant pictorial information; and two consisted of predominantly pictorial formats, supplemented with either related or redundant text. Booher found no differences among the pictorial-only and the predominantly pictorial formats with respect to overall speed and accuracy of task performance; however, subjects in these three conditions were faster and made significantly fewer errors than subjects in the other conditions. In addition, his results showed that subjects in the text-only condition took significantly longer to complete all tasks than subjects who used the other presentation formats. Booher concluded that the predominantly pictorial formats were the only ones that resulted in consistently fast and accurate performance.

The final study in this subcategory (Goff, Schlesinger, & Parlog, 1969) compared the effects of presenting job task instructions when using a combined text-pictorial condition

with those when using a combined audio-pictorial condition. The test subjects were 36 Air Force enlisted personnel, half of whom had not received any training or experience in the maintenance of the C-141 jet aircraft used in the study. The other half consisted of trained personnel who had approximately 2 years of relevant, on-job maintenance experience. Step-by-step instructions for performing various C-141 aircraft maintenance tasks either were presented in booklet form or were narrated to the subjects by means of an audio tape. The text and audio instructions were supplemented with outline drawings that showed the location of parts and/or the actions required to perform the task steps. (An example of instructions presented in the text-pictorial condition is provided in Figure 1.)

There was no difference between the two groups in terms of the number of errors made. However, significant differences in task completion times were obtained for experience level, presentation method, and for the interaction of these factors. Specifically, results showed that: (1) inexperienced subjects took significantly longer to complete component removal and replacement tasks than experienced ones, and (2) subjects who received instructions in booklet form were faster than those who received them via audio tape, both in completing component removal tasks and, for experienced subjects, in completing all tasks.

Comparisons of Multiple-channel Presentations

The studies in this subcategory compared the effectiveness of various audiovisual devices in presenting instructions for equipment-operator, maintenance, and assembly tasks performed by civilian technicians and factory workers. A study by Brown (1964) involved comparisons of two audiovisual devices that provided the information needed to align the master indicator console on a military radar. One device presented integrated text, audio, and pictorial instructions by means of a lightweight apparatus worn on the subject's head; the other provided identical information on a much larger, portable unit. Equal numbers of experienced and inexperienced technicians performed the alignment twice, using the head device for one session and the portable device for the other.

Results showed that the significant differences in the time required to perform the alignment were a function of experience and trial. Specifically, the inexperienced technicians took longer to complete both tasks than than the experienced ones, while the second alignment procedure was performed significantly faster than the first, regardless of the device used to present the information. No differences were found in the time measure as a function of presentation method.

Chalupsky and Kopf (1967) presented the results of interviews with representatives from 12 companies in private industry who had experience with the use of audiovisual JPAs. Included in this publication was an annotated bibliography of relevant research in the area. Items 2, 11, 21, and 23 from their review described benefits associated with using the same portable unit tested in Brown's (1964) study. In general, these studies reported that the audiovisual device significantly increased worker productivity and quality of finished products, and significantly reduced the need for extensive entry-level job training and close supervision.

Theories and Models

The publications reviewed in this section stem largely from two major perspectives: communication theory and information processing theory. These perspectives differ in terms of their focus and objectives, but each arose from a need to understand better the complexities of human communication and information processing.

Communication Theory

Probably the most important model developed in this area was that of Shannon and Weaver (1949). Their work involved a mathematical theory of transmission of electronic signals and described the circumstances under which perfect transmission would occur in the presence of "noise." Part of their explanation took the form of an engineering model that contained the following elements: (1) a source of information, (2) an encoder, (3) a channel for transmission of signals, (4) a source of noise, (5) a decoder, and (6) a message destination--all arranged in linear order.

An implicit assumption of this model is that the same alphabet (i.e., any set of signs such as letters, dots, dashes, or numbers) exists at both the transmitting and receiving ends of the communication channel. Thus, according to the model, it is the function of the information source to select signs from this alphabet to constitute a message. The message is then transmitted in physical form as a signal, through a communication channel, to the decoder. At the decoder, the signal then operates upon an identical alphabet that selects corresponding signs for reconstructing the message before it reaches the destination. Further, it is assumed that the stimulation available to the receiver is message plus noise. The latter includes not only noise in the literal sense of the term, but also irrelevancies intermingled with the intended message.

The Shannon-Weaver model included mathematical expressions to quantify measures of various aspects of communication efficiency, dependability, redundancy, and channel capacity. This ability to obtain quantitative measurements in the area of communication aroused interest in many fields of research and numerous applications followed (e.g., Attneave, 1959; Cherry, 1957; Hsia, 1968a, 1968c). Beyond its technical use, the model facilitated the discussion of different approaches to communication processes by providing a common base. These positive attributes notwithstanding, Travers (1970) criticized the model as being too "mechanistic" by noting that it placed a premium on the physical elements of communication and ignored syntactics, semantics, and the practical elements of communication. In the same vein, Cherry (1957, p. 170) noted that the "theory is written in the meta-language of an external observer; it is not a description of the process of communication as it appears to one of the participants."

Information Processing Theory

As disillusionment with communication theory spread, researchers began developing alternative theoretical formulations, collectively referred to as information processing theory, to guide their work. The primary goal of this theory is to explain the properties of mental behaviors and processes responsible for receiving, storing, retrieving, and using information that may originate either in the external environment or from internal mental states.

An important and influential construct in this area was the limited-capacity channel proposed by Broadbent (1958). Part of Broadbent's theory took the form of an explanatory model whose predictions could be quantified; the model itself did not, however, purport to be a mathematical model. The core concept of this model is a limited-capacity channel, identified as the "P-system," that can handle only a given amount of information in a given time. Broadbent (1965) likened this limited-capacity system to the flow of cars on a freeway: Each lane can handle only so many vehicles per hour; thus its limitation is based on the rate at which "traffic" may flow rather than on the total number of "vehicles" that can be accommodated.

The model also stipulates the conditions under which the P-system acts as a limited-capacity channel. When the rate of incoming information from two or more perceptual systems is sufficiently low, all of the information may pass directly to the P-system. At faster rates of presentation, however, the model predicts that the P-system eventually reaches a point at which it can no longer handle simultaneous inputs from multiple sources. Instead, it will accommodate information from only a single source, thereby functioning as a sequential, single-channel utilization system.

In addition to encompassing findings from his own research efforts, Broadbent's (1958) model provided a theoretical framework that allowed collation of a substantial body of empirical findings from many fields of research. For example, the work of Travers (1964, 1967, 1970) and his associates (e.g., Jester & Travers, 1966; Reid & Travers, 1968; Van Mondfrans & Travers, 1964) extended Broadbent's limited-capacity model to the area of audiovisual communications. These studies generally showed that combined text-audio presentations of redundant information offered no advantage over either of these two channels alone, even when the rate of presenting information was relatively slow (e.g., 200 words per minute or less).

The Travers et al. studies showed that, at faster rates of presentation, two things began to happen. First, evidence of P-system "jamming" was obtained for the combined text-audio condition, suggesting that the use of two information channels resulted in interference of one channel with the other. And second, as this point of information jamming was reached, subjects took steps to block out the nonpreferred information channel (e.g., by closing their eyes and listening intently, or by putting their hands over their ears to block the sound, then reading the information). Collectively, these findings were interpreted as providing support for a basic postulate of the limited-capacity model: that information from two or more sources must ultimately pass through a sequential, as opposed to a simultaneous, information processing system.

Despite the major contribution made by Broadbent's model to information processing theory, various aspects of the model were criticized as additional research began to reveal inconsistencies. With respect to the limited-capacity channel, Mowbray and Rhodes (1959) found that, after sufficient practice, reaction time for selecting among eight simultaneously presented response alternatives was as low as that for two choices. Other studies showed that, in situations having high stimulus-response compatibility, reaction time did not depend on the number of response alternatives (e.g., Davis, Moray, & Treisman, 1961; Leonard, 1959). An additional criticism of the Broadbent model is that it focuses almost exclusively on differences in learning or performance attributable to such factors as channel capacity and the rate at which information is presented. As a result, it fails to consider any differential advantages afforded by the auditory and visual sensory modalities--either separately or combined--as mechanisms for information processing. These shortcomings were addressed by the dual-coding theory advanced by Paivio (1971, 1978).

According to the dual-coding theory, inputs from verbal and nonverbal sources are represented and processed by means of two functionally independent, yet interconnected, cognitive systems. The image system is presumed to specialize in the processing of pictorial information and in generating and analyzing mental images. The verbal system is concerned with the perceptual processing and production of language. The theory holds that each system can be independently accessed by relevant stimuli: the image system is activated more directly by pictures, line drawings, or objects, while the verbal system is activated more directly by written or spoken words. In addition, the theory assumes that both systems are substantially interconnected, since nonverbal information can be

transformed into verbal information (or vice versa) under appropriate conditions. Paivio's theory also includes an explanatory model, consisting of three stages of processing, to account for the integration of information from each system.

The central predictions made by the dual-coding theory are that: (1) information represented by both image and verbal codes is more powerful than that represented by either code alone, but (2) no advantage will accrue to the presentation of redundant information within the same coding system. Paivio and his associates conducted numerous studies they thought supported these predictions. References to this research are listed in an edited volume by Yuille (1983) and in Paivio (1978). Other researchers, independent of Paivio and his associates, have obtained results that generally support the dual-coding concept (e.g., Moyer, 1973; Rabinowitz, Mandler, & Barsalou, 1979; Rafnel & Klatsky, 1978; Tversky, 1969).

Most of the persistent controversy about this theory involves a debate between imagery and propositional theorists. As noted by Anderson (1978), imagery theorists contend that separate coding systems are used to process verbal and visual information. Propositional theorists, on the other hand, contend that both verbal and visual information are coded using the same abstract, amodal format. The model used by Paivio to explain his dual-coding theory was also criticized by Desrochers and Petrusic (1983) because it makes no provision for the temporary storage of stimuli in either the verbal or image systems, nor does it specify the mechanism for selecting responses once stimuli have been processed through the various stages.

Summary

Taken individually, the studies in this review often present conflicting and inconsistent findings concerning the effects of audio and visual presentation methods on learning and performance. Reasonable consistency can be found, however, when studies in each content area are considered together, and particularly when the results from these studies are examined in the context of the various theoretical formulations reviewed. Accordingly, the following paragraphs summarize the major findings and conclusions derived from the publications included in each content area.

One generally consistent finding among studies in academic settings was the superiority of instructional material presented visually to the same material presented aurally. To account for this finding, several authors (e.g., Chapanis, 1965; Day & Beach, 1950; Gropper, 1963; Levie & Dickie, 1973) have suggested that one advantage of information presented visually is the relatively greater referability (i.e., opportunity for reviewing the material) that it affords. Thus, for example, literate adults using textual materials can often obtain more information per unit of time, either by scanning ahead for particular details or by re-reading the material in whole or part, than subjects receiving the same material aurally. Goldstein (1940) found that the less the referability afforded by a visual presentation, the less its advantage over an auditory presentation.

Other authors have suggested that personal experience with information presented in visual or auditory forms may play a role in determining the extent to which one method is superior to the other. The influence of this factor in the context of job performance situations was discussed by Henneman and Long (1954, p. 16) who noted that "in the past, an operator who has received simple direct instructions and orders, as spoken by others, may well respond more efficiently to such messages when presented by voice than when presented visually, in spite of many other considerations." Similar views were expressed by Travers (1970), but his explanation was based on the underdeveloped reading skills

among younger subjects in the context of academic settings. In summary, none of the literature reviewed involving adult subjects suggested the presence of any special ability to extract information from either visual or auditory forms.

Two of the studies reviewed in applied settings showed that a combined text-pictorial format resulted in performance superior to that resulting from the use of text or pictorial instructions alone; while two other studies, which used only dual- or multiple-channel presentations, found essentially no differences between the various methods tested. The studies reviewed by Chalupsky and Kopf (1967) compared job performance when using an audiovisual aid with previously established production standards (e.g., the number of acceptable units produced in a given time period). While the findings of these studies are reasonably consistent, they are too few in number to permit any meaningful generalizations. Other considerations, such as inadequate specification of relevant treatment comparisons and a lack of experimental controls, also limit the overall generality of the findings and conclusions obtained in several cases. For example, in the research reported by Brown (1964), Chalupsky and Kopf (1967), and Goff et al. (1969), no provisions were made for separating the text or audio instructions from the information presented pictorially. Thus, there is no way of determining from these studies whether the text or audio instructions, either separately or combined, would have provided sufficient information with which to perform the job tasks.

In a related vein, no provisions were made in the Goff et al. study for equating the text-pictorial and audio-pictorial methods in terms of the amount of information presented at any one time. Subjects using the text-pictorial method could view any or all of the performance steps listed in booklet form, while those using the audio-pictorial method were presented with only a single performance step at a time. Further, subjects who used written instructions could self-pace the reading of the material, whereas subjects in the audio-pictorial method were paced by the rate at which the narrator spoke. These problems notwithstanding, the studies by Brown (1964) and Goff et al. (1969) found consistent performance differences between subjects as a function of prior training and experience on the tasks sampled. For that reason, it was felt that this factor had direct implications for the design of the present study.

One area in which the predictions from the various theories appear to converge concerns the simultaneous presentation of redundant information in text and audio forms. Both the limited-capacity theory and the dual-coding theory predict that redundant information presented in a text-audio format offers no advantage over the same material presented in either text or audio form alone. It is important to note, however, that the theories differ as to why this is true. According to limited-capacity theory, redundancy between two separate information sources is reduced by a process of categorization; that is, some bits of information are treated as being equivalent by the subject and are "chunked together" into fewer bits of information. The compressed information then enters a central processing system that can handle information presented sequentially but not simultaneously. Dual-coding theory, in contrast, states that, while text and audio inputs are received via separate sensory modalities, each can be simultaneously processed by activating the verbal system, which structures these types of inputs in the same way--through words. It is only when verbal and pictorial representations of related or redundant information are used together that people can use each to its best advantage.

Another perspective on this issue was offered in a series of articles by Hower Hsia (1968b, 1969, 1971, 1977), which describe his interpretation and extension of Shannon and Weaver's (1949) mathematical theory of communication. According to this theory,

communication systems usually employ a redundancy principle to reduce or minimize the adverse effects of error, equivocation, and noise. Hsia (1977) distinguishes between two types of redundancy: one involves the content of information within a single channel; the other, shared information between any dual- or multiple-channel presentation. Regarding the latter, Hsia provides an algebraic formula for computing the precise level of between-channel redundancy (BCR). The end result of this formula is expressed on a bivariate continuum: BCR is optimum when two or more channels transmit identical information (i.e., producing mutual facilitation); and it is zero when the channels emit completely different information (i.e., producing mutual interference).

Hsia (1977) proposes two factors that he feels may account for the many discrepancies regarding single- versus dual- or multiple-channel presentations of redundant information. First, he contends that many experimenters have chosen to ignore quantification of the term redundancy via the mathematical formulations developed by Shannon and Weaver; instead, they have preferred to define it in terms of common usage, in which redundant relationships are interpreted on purely intuitive grounds. Second, he notes that unless stimuli of the same class and type are synchronized, any lagging or staggering may interfere with the orderly processing of the information transmitted. If this problem existed in some of the studies reviewed, it could account partially for the often inconsistent findings reported for dual- or multiple-channel presentations of instructional materials as compared with single-channel presentations.

Plan of the Present Research

A diverse set of stimulus materials, subjects, experimental methods, and theoretical formulations have been used in previous studies for assessing or explaining the effects of audiovisual presentations on human learning and performance. The rationale used for selecting the six presentation methods in this study was that they were generally representative of the types of methods that either had in the past, or could in the future, be used for presenting the information needed to perform job tasks. The experience factor was selected because earlier research found that it accounted for substantial variance in task performance measures. Several experimental hypotheses tested in this study were based on predictions suggested by Paivio's (1971, 1978) dual-coding theory. This formulation was selected because it provided differential predictions regarding the effectiveness of the six presentation methods chosen for comparison.

METHOD

Subjects

Subjects were 180 Navy enlisted personnel from the Naval Training Center, San Diego, California. The subjects ranged from 17 to 34 years in age, had between 9 and 16 years of civilian education, and had between 2 and 36 months of military service. Two groups of subjects were formed: one included 72 males and 18 females who had completed the oscilloscope operator portion of a Basic Electricity and Electronics (BE/E) training course and the other included 90 male recruits who had been designated to receive BE/E training but who had not yet started the course.[2] For each group, subjects were randomly ordered into one of the six experimental treatment conditions, thus there were 15 subjects per condition.

Participation in the testing was strictly voluntary. No one declined to participate, and all subjects appeared interested and cooperative throughout the experimental sessions.

Performance Tasks

The following four performance tasks involving the operation of a standard Navy oscilloscope were used in this study:

Initial Setup and Adjustments

Subjects performed a 33-step procedure to prepare the oscilloscope for operation. The content of instructions for this task was adapted from a Navy oscilloscope operator manual (Naval Sea Systems Command, 1967). In order to meet the criterion for success, ninety-five percent of the steps had to be performed completely, correctly, and in the sequence specified in the instructions.

Probe Calibration

Subjects performed a 20-step procedure to calibrate a divider probe. The content of instructions for this and the two remaining tasks was adapted from an oscilloscope proficiency test developed under Navy contract (Kinton, Inc., 1980). The criterion for successful performance was defined as a perfect square waveform being presented on the oscilloscope display screen subsequent to tightening of the probe-locking collar.

Amplitude Measurement

Subjects performed an 18-step procedure to measure the peak-to-peak amplitude of a test signal. They were also required to write down certain readings and control settings from the oscilloscope and to perform simple arithmetic in computing an amplitude value.

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[2] As initially planned, each subject group was to consist of 90 male Navy enlisted personnel. This requirement was changed in the case of the BE/E group, however, when it was learned that approximately 20 percent of the students enrolled in that course were females. Accordingly, three female BE/E students were assigned at random to each of the six treatment conditions. Comparable numbers of female subjects were not available for testing in the other group, since recruit training for female Navy enlisted personnel is not provided in San Diego.

The acceptable range of accuracy was defined as a measurement between 11.6 and 12.0 volts peak-to-peak.

Frequency Measurement

Subjects performed a 17-step procedure to measure the frequency of a test signal. This task also required oscilloscope readings and control settings to be recorded and arithmetic computations to be performed. The acceptable range of accuracy was defined as a measurement between 6,944 and 7,353 hertz.

The foregoing tasks met several important criteria in that they sampled a wide range of behaviors having practical importance to Navy jobs concerned with the maintenance of electrical and/or electronic equipment; required no specialized knowledge, skills, or reference materials for their solution; and had definitive, predetermined criteria for defining passing or failing performance.

Presentation Methods

Six methods for presenting computer-based instructions were tested, namely:

1. Text-only, in which steps for each task consisted of short statements presented on a computer display monitor.

2. Audio-only, in which the same task steps were presented aurally from a prerecorded sound track.

3. Text-audio, in which the above methods were combined so that the text and audio instructions were presented simultaneously.

4. Text-graphics, in which the text instructions were supplemented with outline drawings of the oscilloscope and related support equipment. In addition, "flashing arrows" were used on these drawings to highlight the particular switch, dial, or control described in the instructions. Figure 2 gives an example of a task step presented by this method.

5. Audio-graphics, in which task steps were presented aurally, supplemented with the same outline drawings described above.

6. Text-audio-graphics, in which text and audio instructions were presented simultaneously, supplemented with outline drawings.

Written instructions for the text-only and text-audio methods usually comprised two or three lines of text with a maximum of 60 characters per line, while those for the text-graphics and text-audio-graphics methods were usually four or five lines of text with a maximum of 32 characters per line. As shown in Figure 2, graphics appeared either below or to the left of the text, which was the configuration used in the text-graphics and text-audio-graphics methods. This same configuration, less the text, was used in the audio-graphics method. For all but the audio-only method, the text and/or graphics information appeared in phosphorescent green against a uniform gray background on the computer display screen.

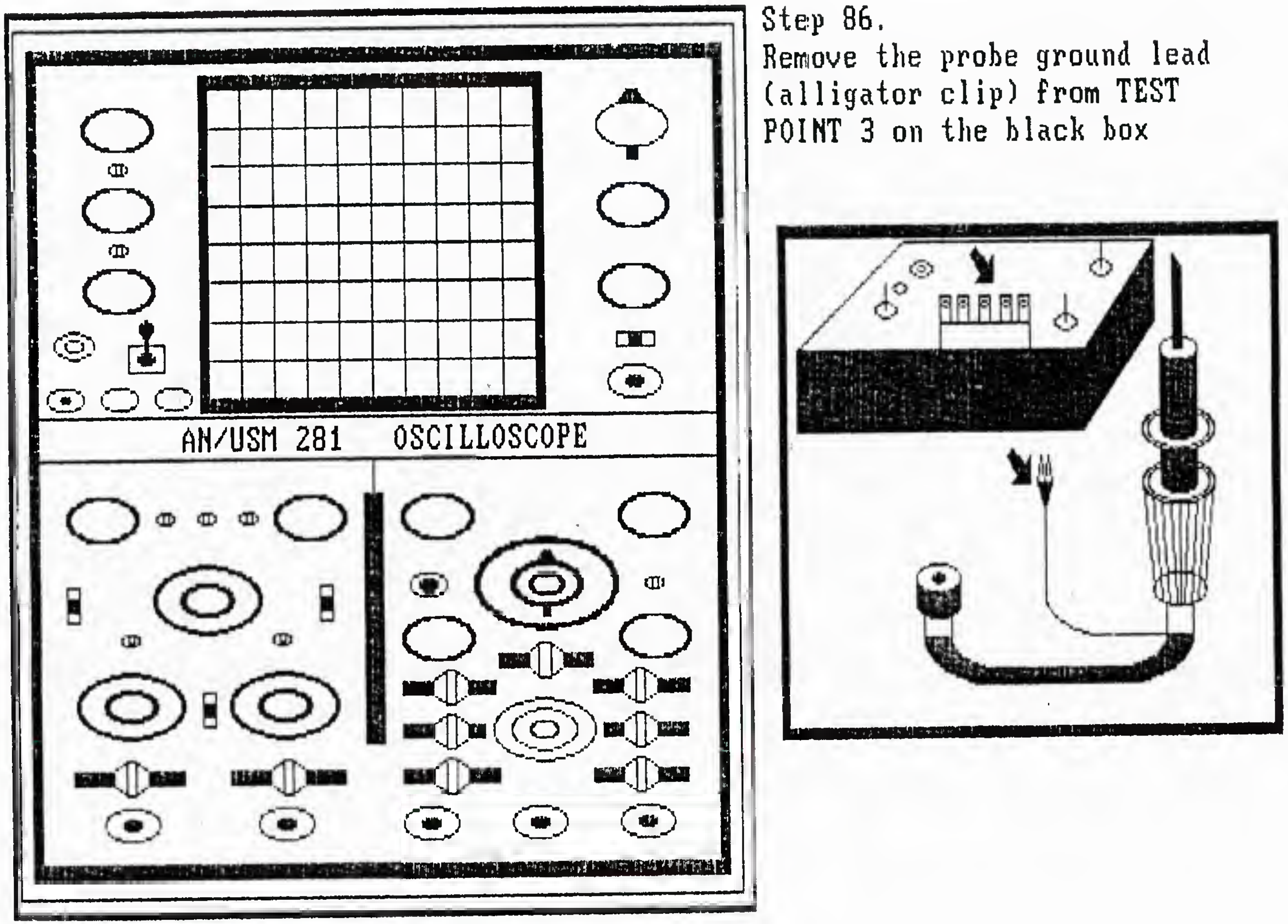

Figure 2. An example of a task step presented by the text-graphics method.

Instructions for presentation methods that included audio were recorded at an average rate of 100 words per minute, which is well below the average oral reading rate ($\underline{M}$ = 175; $\underline{SD}$ = 20) for newscasters and professional readers for the blind (Foulke & Sticht, 1969). The same 100-words-per-minute rate was adopted as the standard for presenting instructions in all conditions. Thus, the text and/or graphics information appeared on the computer display only for as long as it took to present the entire performance step aurally. A computerized time-code system was used to ensure that the rate of presenting all task steps was constant across conditions.

Apparatus

The apparatus, depicted in Figure 3, consisted of the following: (1) a microcomputer and peripherals, (2) a random-access audio disk player/recorder, (3) an oscilloscope and associated support equipment, and (4) videotape equipment. Each is described in more detail below.

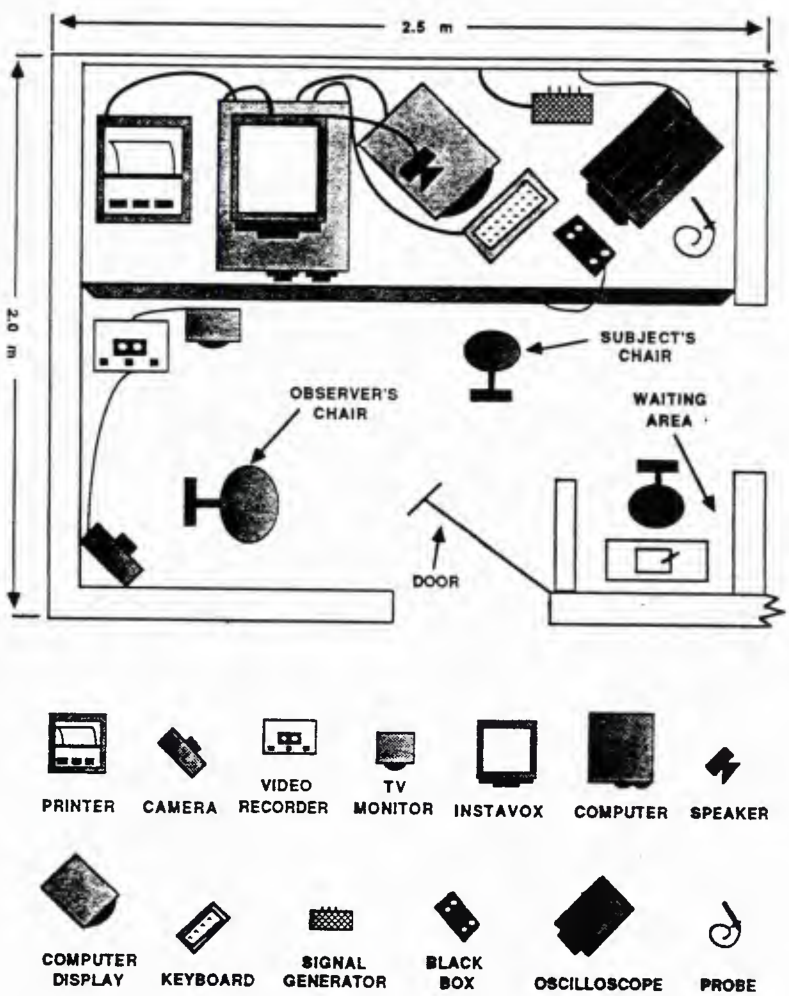

Figure 3. Arrangement of apparatus in the mobile laboratory.

Microcomputer System

This system was used for presenting instructions in all six conditions and for automatically recording certain dependent variable measures. It consisted of a microcomputer (IBM model XT)[3] equipped with an internal clock card, an asynchronous communications card, and a monochromatic graphics/printer interface card (Hercules model HGC). The computer was also connected to a standard personal computer keyboard and monochromatic, 17 x 25 cm display monitor (both IBM products).

Two keys on the computer keyboard were programmed as "command" keys. These keys, which occupied the numeric characters one and zero on the uppermost keyboard row, were used by subjects for advancing to the next instruction in the task sequence or for repeating the most recently presented one. The numeral one and zero keys had affixed "ADVANCE" and "REPEAT" labels, respectively, to facilitate their identification by the subjects. The computer was also programmed to record automatically each subject's start and stop times and the number of steps repeated for each task. Listings of these data were obtained from a line printer (Qume model Sprint-11) connected to the microcomputer.

Audio Disk System

This system was used to present instructions for the four conditions that used audio. It consisted of a random-access audio disk player/recorder (INSTAVOX model RA-12A) that was connected to the microcomputer and to an external speaker (Grason-Stadler model E700A-2). The instructions recorded on this system were presented at an average volume level of 75 decibels.

Oscilloscope and Related Equipment

This system was used to support the subject's performance of the tasks. It consisted of an oscilloscope (Tektronix model AN/USM-281), a 10-megaohm divider probe (Tektronix model P6006), a test signal generator (Continental Specialties model 2001), a six-function pocket calculator (Light Power), and a "black box" apparatus that was designed for an earlier research project involving the AN/USM-281 oscilloscope (Nugent, Laabs, & Panell, 1982).

External labels were affixed or modified on three of the above equipments to identify various components that subjects were required to use while performing the tasks. For example, the following labels were affixed to components of the divider probe: PROBE BODY AND TIP, LOCKING COLLAR, and BNC CONNECTOR. These labels corresponded exactly with those used to name the components in the task steps. A similar procedure was used to label components on the black box and oscilloscope.

Videotape System

This system was used to videotape performances of a sample of subjects in each of the 12 combinations of subject group and treatment conditions. It consisted of a low light-level television camera and video processor unit (Sony model AVC-1450), a videotape recorder unit (Sony model SLO-320), and a television monitor (Sony model CVM-115).

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[3]Identification of the equipment used in this study is for documentation purposes only and does not imply endorsement.

Procedure

The subjects were tested individually in a large mobile laboratory belonging to the Navy Personnel Research and Development Center, San Diego, California. Instructions were read aloud to the subject at the outset of the session to provide a general orientation to the performance tasks and data collection methods. Voluntary participation was explained and procedures for maintaining subject anonymity were described, followed by distribution of a background information form (Appendix A).

After a subject was randomly assigned to a presentation method, standardized instructions specific to that method were read aloud. The subject next performed a four-step practice exercise that was designed to provide familiarization with the method of presenting task instructions, the types of actions to be performed, and the use of the command keys.

Instructions for each oscilloscope operator task were then read aloud, with subjects performing them in the following fixed order: initial setup and adjustments, probe calibration, amplitude measurement, and frequency measurement.[4] Each set of instructions began with a statement describing the purpose of the task to be performed, followed by supplementary information concerning such items as appropriate use of the command keys and where to record various readings and values obtained. These instructions also advised the subject that the experimenter would not answer questions or provide assistance during performance of the task, but that the subject would be informed when the task had been completed. Equipment settings and adjustments were standardized prior to the administration of each task. An example of relevant equipment control settings used prior to each subject's performance of the probe calibration task is given in Appendix B.

Data Collection Forms

Three basic forms were used for recording subjects' task performance and attitudinal data. One of these, termed the performance observation form, was used by the experimenter to record errors that subjects made during their performance of the tasks. A zero value was assigned for task steps that were performed incorrectly or out of sequence (omitted steps were considered as being performed both incorrectly and out of sequence). Spaces were also provided on the forms for recording the specific reason(s) why a zero value was assigned to any given task step. Appendix C provides an example of the observation form used to assess each subject's performance during the initial setup and adjustment task.

The second form, termed the examinee worksheet, was completed by the subject during his or her performance of the amplitude and frequency measurement tasks. This form contained spaces for recording oscilloscope readings and the results of various arithmetic computations (see Appendix D).

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[4]Counterbalancing for task order effects was rejected because such an approach could result in potential damage to the oscilloscope and its associated support equipment. Moreover, the particular task presentation order used is the only one that is consistent with standard Navy procedures for the operation of oscilloscopes.

The third form, a user evaluation questionnaire, was completed by each subject immediately after the frequency measurement task had been completed. The first section of the questionnaire contained items for rating various physical features of the equipment used to support the subject's performance of the tasks, while the second section involved rating the acceptability of the method used to present the task instructions. The third section provided spaces for making comments, complaints, or suggestions (Appendix E).

Video Recordings

Task performances were recorded on videotape for 36 (20%) of the 180 subjects tested. This subset was formed by selecting 3 subjects from each of the 12 combinations of subject groups and treatment conditions. Within each of these combinations, 1 subject was selected at random from each one-third of the 15 subjects tested (i.e., 1 subject from the first-, middle-, and last-third, respectively). Videotaping established a permanent record of oscilloscope operator task performances for subsequent review and analysis.

Debriefing

The test session, which lasted an average of 50 minutes per subject, ended with a discussion of the purpose of the study, together with a thorough review of the subject's performance on the tasks. Subjects were thanked for participating and asked to refrain from discussing details of the study with others who had yet to be tested.

Experimental Hypotheses and Design

The following hypotheses served as the framework for comparing task performance as a function of subject group and presentation method:

I. As a group, BE/E subjects will demonstrate better task performance (defined as faster time to completion, more tasks performed correctly, fewer steps repeated, fewer steps performed incorrectly, and fewer steps performed out of sequence) than the recruit subjects.

II. For both groups, subjects assigned to presentation methods that include graphics will demonstrate better task performance than subjects assigned to methods that exclude graphics.

III. For both groups, no difference in task performance will be found between subjects assigned to the text-audio method and subjects assigned to the text-only and audio-only methods.

IV. For both groups, no difference in task performance will be found between subjects assigned to the text-audio-graphics method and subjects assigned to the text-graphics and audio-graphics methods.

The independent variables of subject group and presentation method were arranged in a 2 X 6 between-subjects multiple analysis of variance (MANOVA) design for preliminary analyses of the data. In subsequent analyses, this design was reduced to a series of single-factor, between-subjects MANOVAs to test the validity of the experimental hypotheses

described above.[5] Additionally, five categories of performance measures were included in the analyses of the oscilloscope operator tasks taken both separately and overall (i.e., summed across tasks). The specific variables that comprised these five categories included: time-to-task completion, dichotomous (pass or fail) performance scores, and separate frequency counts for task steps that were repeated, performed incorrectly, or performed out of sequence. Taken together, the four sets of five outcome measures for the separate tasks and the one set of five overall task performance measures yielded a total of 25 dependent variables for use in subsequent data analyses.

RESULTS

The means and standard deviations for the five categories of performance measures used in this study (cross-tabulated by tasks, groups, and presentation methods) are presented in Table 1. The individual scores upon which Table 1 is based were submitted to the MANOVA designs described in the previous section.

Preliminary Analyses

Four separate analyses were conducted preparatory to the main tests of the experimental hypotheses. The purposes of these analyses were to determine: (1) whether a statistically significant interaction existed between the subject grouping and presentation method factors, (2) whether performance differences existed between the male and female subjects who comprised the BE/E group, (3) whether subjects included in each group and presentation method were comparable in terms of certain background characteristics, and (4) whether these background characteristics warranted inclusion as covariates in subsequent data analyses.

Interaction Effects

Because all main tests of the experimental hypotheses were necessarily limited to a single between-subjects factor, the first analysis was particularly important in determining whether the effect of the subject grouping factor was the same across all levels of the presentation method factor. Accordingly, performance outcome measures for all subjects were included in the 2 X 6 between-subjects MANOVA design described earlier. Results showed a nonsignificant multivariate F-ratio for the interaction between these two factors on the separate ($F(100, 765) = 1.12$, $p < .20$) and overall ($F(25, 840) = 1.00$, $p < .50$) task measures. This analysis did, however, yield significant multivariate F-ratios for the main effect of each factor separately, results of which are discussed later in this section.

[5] A split-plot MANOVA design that would include the four tasks as a within-subjects (repeated measures) factor was considered but rejected as inappropriate. The principal reason for rejecting this design concerned the lack of parallelism among tasks in terms of their difficulty level and the number and type of actions each required.

Table I

Means and Standard Deviations for Performance Measures on Separate and Overall Tasks by Subject Groups and Presentation Methods[a]

Group	Method[b]	Setup					Probe					Amplitude					Frequency					Overall				
		Time	Repeats	Control Setting Errors	Sequence Errors	Success Criterion	Time	Repeats	Control Setting Errors	Sequence Errors	Success Criterion	Time	Repeats	Control Setting Errors	Sequence Errors	Success Criterion	Time	Repeats	Control Setting Errors	Sequence Errors	Success Criterion	Time	Repeats	Control Setting Errors	Sequence Errors	Success Criterion
Recruit	1. T-only	11.8 (2.7)	10.1 (4.9)	1.6 (1.0)	2.0 (1.3)	0.4 (0.5)	10.9 (2.3)	8.9 (4.1)	1.9 (1.1)	0.7 (0.6)	0.7 (0.5)	11.2 (2.6)	8.3 (4.5)	3.0 (2.5)	0.9 (1.1)	0.5 (0.5)	9.7 (2.8)	4.0 (2.8)	2.9 (2.5)	0.4 (0.9)	0.3 0.5)	43.7 (8.2)	31.3 (13.3)	9.3 (4.7)	4.0 (2.4)	2.0 (1.1)
	2. A-only	11.3 (2.7)	4.4 (3.1)	1.6 (1.4)	1.5 (1.5)	0.6 (0.5)	10.9 (2.8)	4.3 (3.2)	2.1 (2.0)	1.2 (1.2)	0.7 (0.5)	9.8 (1.9)	3.8 (1.7)	3.9 (2.3)	1.3 (1.0)	0.4 (0.5)	8.7 (2.0)	1.8 (1.9)	2.1 (1.3)	0.3 (0.7)	0.2 (0.4)	40.7 (8.4)	14.3 (7.2)	9.6 (4.1)	4.3 (2.1)	1.9 (0.7)
	3. T+A	12.5 (2.3)	6.7 (4.3)	1.2 (1.1)	1.7 (2.0)	0.7 (0.5)	10.4 (2.4)	4.7 (3.1)	1.5 (1.3)	0.5 (0.8)	0.4 (0.5)	10.1 (1.5)	4.8 (2.8)	3.0 (2.1)	1.0 (0.9)	0.3 (0.5)	9.2 (2.1)	2.2 (1.8)	1.1 (1.3)	0.2 (0.5)	0.6 (0.5)	42.3 (6.3)	18.4 (10.2)	6.7 (3.2)	3.4 (2.4)	2.1 (1.0)
	4. T+G	8.6 (2.1)	4.3 (3.3)	1.5 (1.1)	1.2 (0.9)	0.6 (0.5)	8.8 (2.1)	5.6 (4.3)	2.5 (1.8)	1.0 (1.4)	0.5 (0.5)	9.5 (1.6)	5.8 (3.3)	4.5 (2.0)	1.5 (1.2)	0.3 (0.5)	8.3 (2.8)	2.9 (2.2)	2.2 (1.3)	0.3 (0.7)	0.1 (0.4)	35.2 (6.7)	18.6 (11.4)	10.7 (4.2)	4.0 (1.9)	1.5 (1.2)
	5. A+G	8.5 (1.3)	1.2 (1.7)	1.0 (1.5)	0.9 (1.2)	0.7 (0.5)	9.1 (2.6)	1.3 (1.5)	1.2 (1.0)	0.4 (0.6)	0.9 (0.4)	8.8 (1.4)	2.4 (1.7)	3.9 (2.5)	0.9 (1.2)	0.4 (0.5)	7.5 (1.1)	0.7 (0.6)	1.7 (1.9)	0.3 (0.7)	0.4 (0.5)	33.9 (4.8)	5.7 (4.3)	7.7 (4.6)	2.6 (2.8)	2.3 (0.8)
	6. T+A+G	8.4 (1.1)	1.2 (1.3)	1.6 (2.1)	0.5 (1.1)	0.7 (0.5)	8.7 (1.9)	2.9 (2.4)	1.2 (1.4)	0.4 (0.8)	0.9 (0.3)	9.0 (2.0)	2.4 (1.8)	2.5 (2.0)	0.5 (1.0)	0.5 (0.5)	8.1 (1.4)	1.3 (1.3)	2.5 (2.2)	0.4 (0.7)	0.3 (0.5)	34.2 (4.4)	7.8 (5.2)	7.9 (4.4)	1.9 (2.4)	2.5 (1.0)
Recruits across methods		10.2 (2.7)	4.7 (4.5)	1.4 (1.4)	1.3 (1.4)	0.6 (0.5)	9.8 (2.5)	4.6 (3.9)	1.7 (1.5)	0.7 (1.0)	0.7 (0.5)	9.8 (2.0)	4.6 (3.5)	3.5 (2.3)	1.0 (1.1)	0.4 (0.5)	8.6 (2.2)	2.2 (2.1)	2.1 (1.9)	0.3 (0.7)	0.3 (0.5)	38.3 (7.6)	16.0 (12.3)	8.7 (4.3)	3.4 (2.4)	2.1 (1.0)
BE/E	1. T-only	10.4 (1.6)	8.6 (3.8)	1.9 (1.0)	1.7 (1.0)	0.3 (0.5)	8.9 (2.7)	6.5 (4.9)	0.9 (1.1)	0.6 (0.9)	0.7 (0.5)	8.5 (1.9)	4.1 (2.9)	1.7 (0.5)	0.6 (0.6)	0.7 (0.5)	8.7 (1.7)	3.3 (2.8)	2.9 (2.1)	0.2 (0.6)	0.3 (0.5)	36.5 (6.3)	22.4 (10.8)	7.4 (4.0)	3.1 (1.7)	2.1 (1.0)
	2. A-only	9.8 (2.0)	2.4 (1.1)	1.3 (1.5)	1.3 (1.5)	0.7 (0.5)	8.8 (2.4)	3.6 (2.8)	1.0 (1.2)	1.0 (1.7)	0.9 (0.3)	8.8 (1.7)	2.1 (2.1)	2.0 (1.7)	0.6 (0.8)	0.7 (0.5)	8.3 (2.0)	1.4 (1.2)	1.5 (1.4)	0.4 (0.9)	0.7 (0.5)	35.8 (5.4)	9.5 (5.0)	5.8 (3.2)	3.5 (2.9)	3.1 (0.8)
	3. T+A	9.3 (2.0)	3.2 (2.1)	1.3 (1.3)	1.1 (1.3)	0.8 (0.4)	8.0 (1.2)	2.4 (2.1)	0.4 (0.8)	0.6 (0.9)	1.0 (0)	8.2 (2.4)	2.3 (2.1)	1.9 (1.9)	0.6 (0.9)	0.5 (0.5)	8.7 (2.4)	2.0 (2.2)	2.7 (2.5)	1.3 (0.4)	0.5 (0.5)	34.3 (6.5)	9.9 (6.0)	6.3 (3.8)	2.4 (1.9)	2.8 (0.8)
	4. T+G	8.0 (2.1)	4.9 (3.3)	0.9 (1.1)	0.8 (0.9)	0.8 (0.5)	7.8 (2.2)	4.3 (4.7)	0.8 (0.9)	0.7 (0.9)	0.7 (0.5)	8.6 (2.6)	3.3 (3.2)	3.2 (1.7)	0.6 (0.7)	0.3 (0.5)	8.6 (2.4)	2.6 (2.4)	1.6 (2.2)	0.0 (0)	0.7 (0.5)	33.1 (7.5)	15.1 (13.5)	6.5 (4.0)	2.1 (2.0)	2.4 (1.1)
	5. A+G	7.8 (0.6)	1.1 (1.5)	0.8 (1.1)	0.8 (1.1)	0.7 (0.5)	7.4 (1.0)	1.4 (1.5)	0.9 (1.0)	0.8 (1.4)	0.8 (0.4)	7.6 (1.3)	1.3 (1.9)	2.2 (1.9)	1.1 (1.1)	0.7 (0.5)	7.8 (1.4)	0.9 (1.1)	2.1 (2.3)	0.3 (0.7)	0.7 (0.5)	30.6 (3.1)	4.7 (4.8)	6.0 (4.2)	3.0 (2.8)	2.9 (1.2)
	6. T+A+G	8.2 (1.3)	1.6 (2.2)	0.4 (0.5)	0.4 (0.5)	1.0 (0)	7.5 (1.5)	1.3 (1.3)	0.7 (0.6)	0.9 (1.2)	0.9 (0.4)	7.9 (1.9)	0.9 (1.1)	2.3 (1.9)	0.5 (0.8)	0.5 (0.5)	8.7 (1.9)	0.9 (1.0)	2.1 (2.5)	0.3 (0.5)	0.7 (0.5)	32.4 (5.0)	4.7 (4.6)	5.4 (3.0)	2.1 (1.9)	3.1 (0.8)
BE/E across methods		8.9 (1.9)	3.6 (3.9)	1.1 (1.2)	1.0 (1.2)	0.7 (0.4)	8.1 (2.0)	3.2 (3.6)	0.8 (0.9)	0.8 (1.2)	0.8 (0.4)	8.3 (2.0)	2.3 (2.5)	2.2 (1.9)	0.7 (0.8)	0.5 (0.5)	8.4 (2.0)	1.9 (2.0)	2.1 (2.2)	0.2 (0.6)	0.6 (0.5)	33.8 (6.0)	11.1 (10.1)	6.2 (3.7)	2.7 (2.3)	2.7 (1.0)

[a]Standard deviations enclosed in parentheses.

[b]Legend: T = Text, A = Audio, G = Graphics.

Gender Effects

The second analysis compared male and female BE/E students in terms of their performance on the separate and overall tasks. Specifically, in the event that the task performance of the 18 female BE/E students was found to be superior to that of the 72 male BE/E students (or vice versa), such an effect would have to be accounted for either by including the subject's gender as an additional factor in subsequent analyses of the BE/E group data, or by removing the 18 female subjects altogether, thereby requiring a commensurate reduction in the recruit sample to maintain equal cell sizes in each presentation method. These procedures were not needed, however, since the multivariate *F*-ratios for the interaction between the gender and presentation method factors and the main effect for the gender variable failed to reach statistical significance on both the separate and overall task measures.

Comparability on Background Variables

The third analysis focused on the comparability of the 12 groups of subjects in terms of the following personal background variables: age, years of formal education, and prior civilian schooling or work experience in electricity or electronics.[6] To accomplish this, three separate univariate analyses of variance (ANOVAs) were performed in which the above background characteristics served as dependent variables, with the subject group and presentation methods serving as independent variables. Results showed nonsignificant *F*-ratios for the main effects of the two between-subjects factors and their associated two-way interactions in all three ANOVAs.

Potential Covariates

This analysis compared performance on separate and overall tasks using the above background characteristics as 2-level factors in separate 2 X 2 X 6 between-subjects MANOVAs. The two factor levels for the age and education variables were formed by dividing each distribution at its respective median, while the third background variable (i.e., prior civilian schooling or work experience in electricity/electronics) assumed the same dichotomous values described in footnote 6. MANOVA results showed nonsignificant *F*-ratios for all interaction terms and main effects for these background variables on the separate and overall task measures; consequently their use in subsequent analyses was abandoned.

Main Analyses

The following four sections present results from the main tests of the experimental hypotheses. The reader should refer to Table 1 for a listing of the mean values compared in each of these tests.

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[6]The latter variable, which was based on the subject's responses to questions 8 and 9 on the Background Information Form, was coded "0" if both questions were answered in the negative and "1" if either or both questions were answered in the affirmative. Other items on the Background Information Form were excluded from further consideration because of insufficient variability in the distribution of subjects' responses.

Hypothesis I

This hypothesis predicted better task performance by the BE/E subjects than by the recruit subjects. Relevant data were analyzed in five MANOVAs (one each for the separate and overall task measures), which included the subject groups as two levels of the between-subjects factor. A summary of the results obtained in these analyses is presented in Table 2. Part I of this table shows significant multivariate F-ratios for both the separate and overall tasks; thus, these data provide a basis for rejecting the null hypothesis that BE/E and recruit subjects would perform equally well on the tasks. Given these findings, it is appropriate to examine univariate F-ratios to identify the specific variables on which the two subject groups differed.

Accordingly, as shown in Table 2, Part II, significant differences were found between the two subject groups with respect to: (1) the time variable on the setup task; (2) all variables except sequence errors on the probe task; (3) all variables except the success criterion on the amplitude task; (4) the success criterion on the frequency task; and (5) all variables except sequence errors on the overall tasks. With the exception of sequence errors on the probe task, the performance of the BE/E group was superior to the recruit group.

A relative index of the strength of the subject-grouping factor on the various performance outcome measures is provided in the last column of Table 2, Part II. Inspection of the ω^2 values shows a range from 2 to 14 percent. One method for interpreting these values was provided by Cohen (1977, pp. 284-288), who suggested that "a 'large' effect in the behavioral and social sciences is an experiment that produces a ω^2 value of .15; a 'medium' effect is .06; and a 'small' effect is .01." While such arbitrary distinctions can be questioned, this rough scale provides some perspective with which to interpret the strength of the subject-grouping factor. Based on Cohen's scale, prior training and experience in the operation of oscilloscopes had only a small-to-medium effect on the variance in the performance outcome measures. In summary, the foregoing results generally support Hypothesis I in terms of the probe, amplitude, and overall tasks but provide only limited support for the hypothesis in the case of the setup and frequency tasks.

Hypothesis II

This hypothesis predicted better task performance by subjects whose presentation method included graphics than by subjects whose methods excluded graphics. Relevant data were analyzed using five MANOVAs in which the inclusion or exclusion of graphics served as the two levels of the between-subjects factor. Results from these analyses are summarized in Table 3.

Part I of this table shows significant multivariate F-ratios between presentation methods that included graphics and those that did not for all but the frequency task. To get some idea of the specific variables on which these methods differed, Table 3, Part II, shows significant univariate F-ratios for all five categories of measures used to assess performance on the setup task; the time and repeat measures on the probe and amplitude tasks; and the time, repeat, and sequence measures on the overall tasks. The performance of subjects using methods that included graphics was superior to that of subjects using methods that excluded them, thus these data partially confirm the pattern of results predicted by Hypothesis II.

Table 2

Recruit Versus BE/E Group Performance on Separate and Overall Tasks

Part I : Multivariate tests with 5, 174 degrees of freedom (df) .

Unit of Analysis	Trace V [a]	F	p <
Setup Task	0.081	3.09	.05
Probe Task	0.237	10.81	.01
Amplitude Task	0.222	9.91	.01
Frequency Task	0.154	6.33	.01
Overall Tasks	0.673	6.82	.01

Part II : Univariate tests with 1, 178 df .

Setup Task

Variable	Numerator MS	Error MS	F	p <	ω^2 [b]
Time	0.637	0.051	12.49	.01	.06
Repeats	2.264	0.914	2.47	.12	----
Control Setting Errors	0.588	0.226	2.60	.11	----
Sequence Errors	0.433	0.233	1.86	.18	----
Success Criterion	0.672	0.219	3.06	.08	----

Probe Task

Variable	Numerator MS	Error MS	F	p <	ω^2
Time	1.590	0.054	29.44	.01	.14
Repeats	5.244	0.729	7.19	.01	.03
Control Setting Errors	4.862	0.201	24.19	.01	.11
Sequence Errors	0.001	0.182	0.01	.94	----
Success Criterion	0.800	0.176	4.54	.05	----

[a] Multivariate F-ratios were based on the trace V statistic described in K.C.S. Pillai (1955).

[b] For significant univariate F-ratios, omega squared (ω^2) provides a relative index of treatment magnitude (i.e., the proportion of variance in outcome measures accounted for by the independent variable).

Table 2 (Continued)

Part II : Univariate tests with 1, 178 df .

Amplitude Task

Variable	Numerator MS	Error MS	F	p <	ω^2
Time	1.264	0.048	26.33	.01	.12
Repeats	15.677	0.547	28.66	.01	.13
Control Setting Errors	5.782	0.364	15.88	.01	.08
Sequence Errors	0.865	0.168	5.14	.05	.02
Success Criterion	0.939	0.247	3.80	.06	----

Frequency Task

Variable	Numerator MS	Error MS	F	p <	ω^2
Time	0.003	0.050	0.06	.82	----
Repeats	0.442	0.383	1.15	.29	----
Control Setting Errors	0.005	0.382	0.01	.91	----
Sequence Errors	0.076	0.082	0.93	.34	----
Success Criterion	2.939	0.236	12.45	.01	.06

Overall Tasks

Variable	Numerator MS	Error MS	F	p <	ω^2
Time	0.673	0.033	20.39	.01	.12
Repeats	20.590	2.142	9.61	.01	.08
Control Setting Errors	8.721	0.542	16.09	.01	.08
Sequence Errors	1.384	0.441	3.13	.08	----
Success Criteria	1.805	0.107	16.87	.01	.09

Table 3

Comparison of Methods that Included Graphics Versus Methods that Excluded Them on Separate Overall Tasks

Part I : Multivariate tests with 5, 174 degrees of freedom (df).

Unit of Analysis	Trace V	F	p <
Setup Task	0.372	20.59	.01
Probe Task	0.140	5.67	.01
Amplitude Task	0.097	3.76	.01
Frequency Task	0.051	1.87	.11
Overall Tasks	0.227	10.24	.01

Part II : Univariate tests with 1, 178 df .[a]

Setup Task

Variable	Numerator MS	Error MS	F	p <	ω^2
Time	3.148	0.037	85.08	.01	.32
Repeats	35.721	0.726	49.20	.01	.21
Control Setting Errors	1.692	0.220	7.69	.01	.04
Sequence Errors	4.362	0.211	20.67	.01	.10
Success Criterion	1.250	0.216	5.79	.05	.03

Probe Task

Variable	Numerator MS	Error MS	F	p <	ω^2
Time	1.062	0.057	18.63	.01	.09
Repeats	14.720	0.675	21.80	.01	.10
Control Setting Errors	0.009	0.228	0.04	.84	----
Sequence Errors	0.033	0.181	0.18	.67	----
Success Criterion	0.022	0.181	0.12	.73	----

[a] Univariate results are not listed for the frequency task due to the nonsignificant F-ratio obtained for it at the multivariate level of analysis (see Part I above) .

Table 3 (Continued)

Part II : Univariate tests with 1, 178 df .

Amplitude Task

Variable	Numerator MS	Error MS	F	p <	ω^2
Time	0.392	0.053	7.39	.01	.03
Repeats	7.133	0.595	11.98	.01	.06
Control Setting Errors	1.131	0.391	2.89	.10	----
Sequence Errors	0.001	0.172	0.01	.97	----
Success Criterion	0.272	0.251	1.08	.30	----

Overall Tasks

Variable	Numerator MS	Error MS	F	p <	ω^2
Time	1.029	0.031	33.19	.01	.15
Repeats	63.944	1.898	33.69	.01	.15
Control Setting Errors	0.075	0.591	0.13	.72	----
Sequence Errors	3.545	0.428	8.28	.01	.04
Success Criteria	0.049	0.117	0.42	.52	----

The magnitudes of the ω^2 values listed in Part II of Table 3 suggest that the between-subjects factor included in these analyses had a pronounced effect on the time and repeat measures for the setup and overall tasks. This effect diminished, however, for the remaining performance outcome measures.

Hypothesis III

This hypothesis predicted no differences in task performance among subjects whose presentation method excluded graphics. Accordingly, relevant data were analyzed in five MANOVAs in which the presentation methods that excluded graphics served as three levels of the between-subjects factor. Results of these MANOVAs are summarized in Table 4. Part I of this table shows statistically significant F-ratios for both the separate and overall oscilloscope operator tasks, thus these data provide a basis for rejecting the third experimental hypothesis. Part II of this table shows significant univariate F-ratios for the repeat measures in all cases and for the criterion measure on the setup task.

Results from application of the Tukey (1949) procedure for comparing group means subsequent to ANOVA showed that subjects using the text-only method repeated significantly more task steps than subjects using the audio-only and text-audio methods ($p < .05$ in all cases). Further, a significantly larger proportion of subjects using the text-only method failed to reach the criterion for successful completion of the setup task than did those using the other two methods ($p < .05$). In addition, the magnitudes of the ω^2 values listed in Part II of Table 4 suggest that the inclusion or exclusion of auditory instructions had a relatively large effect on the repeat measures for both the separate and overall tasks, but a somewhat weaker effect for the success criterion measure on the setup task.

Hypothesis IV

This hypothesis predicted no difference in task performance among subjects whose presentation methods included graphics. Relevant data were analyzed in five MANOVAs wherein the between-subjects factor was represented by the three presentation methods that included graphics. Results of these analyses are presented in Table 5. Part I of this table shows significant F-ratios across the separate and overall tasks; consequently, these data provide a basis for rejecting the fourth experimental hypothesis. As shown in Part II of this table, significant univariate F-ratios were obtained for the repeat measures in all cases; for control setting errors on the amplitude task; and for the success criterion on the probe and overall tasks.

Application of the Tukey post-hoc analysis procedure ($p < .05$ in all cases) showed that, on the average: (1) subjects using the text-graphics method repeated more steps on the separate and overall tasks than subjects using the other two methods; (2) more control setting errors were made on the amplitude task by subjects who used the text-graphics method than by those who used the text-audio-graphics method; (3) a larger proportion of subjects using the text-graphics method did not reach the criterion for successful performance on the probe task than subjects using the audio-graphics method; and (4) overall success in performing the tasks was significantly higher for subjects using the audio-graphics and text-audio-graphics methods than for subjects who used the text-graphics method.

The magnitudes of the ω^2 values listed in this table are generally consistent with those for the previous MANOVA. These results again suggest that the inclusion or exclusion of auditory instructions had a pronounced effect on the repeat measures obtained for the separate and overall tasks, but had only a small-to-moderate effect on the remaining performance outcome measures.

Table 4

Comparison of Methods that Excluded Graphics on Separate and Overall Tasks

Part I : Multivariate tests with 10, 168 degrees of freedom (df).

Unit of Analysis	Trace V	F	p <
Setup Task	0.495	5.53	.01
Probe Task	0.382	3.97	.01
Amplitude Task	0.302	2.99	.01
Frequency Task	0.212	1.98	.05
Overall Tasks	0.459	5.50	.01

Part II : Univariate tests with 2, 87 df .

Setup Task

Variable	Numerator MS	Error MS	F	p <	ω^2
Time	0.020	0.048	0.42	.66	----
Repeats	11.154	0.522	21.36	.01	.31
Control Setting Errors	0.339	0.193	1.75	.18	----
Sequence Errors	0.373	0.235	1.58	.22	----
Success Criterion	1.144	0.224	5.11	.01	.08

Probe Task

Variable	Numerator MS	Error MS	F	p <	ω^2
Time	0.039	0.062	.63	.53	----
Repeats	6.406	0.574	11.16	.01	.18
Control Setting Errors	0.385	0.246	1.56	.22	----
Sequence Errors	0.341	0.178	1.92	.16	----
Success Criterion	0.144	0.188	0.76	.47	----

Amplitude Task

Variable	Numerator MS	Error MS	F	p <	ω^2
Time	0.034	0.056	0.61	.54	----
Repeats	3.943	0.565	6.97	.01	.12
Control Setting Errors	0.359	0.403	0.89	.42	----
Sequence Errors	0.057	0.155	0.37	.70	----
Success Criterion	0.211	0.253	0.83	.44	----

Table 4 (Continued)

Part II : Univariate tests with 2, 87 df .

Frequency Task

Variable	Numerator MS	Error MS	F	p <	ω^2
Time	0.046	0.050	0.92	.41	----
Repeats	2.698	0.379	7.12	.01	.12
Control Setting Errors	1.025	0.371	2.76	.07	----
Sequence Errors	0.043	0.088	0.49	.62	----
Success Criterion	0.411	0.247	1.66	.20	----

Overall Tasks

Variable	Numerator MS	Error MS	F	p <	ω^2
Time	0.020	0.036	0.56	.57	----
Repeats	25.243	1.351	18.68	.01	.28
Control Setting Errors	0.828	0.551	1.50	.23	----
Sequence Errors	0.515	0.348	1.48	.23	----
Success Criteria	0.217	0.097	2.23	.12	----

Table 5

Comparison of Methods that Included Graphics on Separate and Overall Tasks

Part I : Multivariate tests with 10, 168 degrees of freedom (df).

Unit of Analysis	Trace V	F	p <
Setup Task	0.420	4.47	.01
Probe Task	0.449	4.86	.01
Amplitude Task	0.328	3.29	.01
Frequency Task	0.323	3.24	.01
Overall Tasks	0.482	5.33	.01

Part II : Univariate tests with 2, 87 df .

Setup Task

Variable	Numerator MS	Error MS	F	p <	ω^2
Time	0.002	0.027	0.07	.91	----
Repeats	7.210	0.540	13.35	.01	.22
Control Setting Errors	0.220	0.245	0.90	.41	----
Sequence Errors	0.449	0.177	2.53	.09	----
Success Criterion	0.278	0.185	1.50	.23	----

Probe Task

Variable	Numerator MS	Error MS	F	p <	ω^2
Time	0.001	0.054	0.02	.98	----
Repeats	6.501	0.511	12.72	.01	.21
Control Setting Errors	0.465	0.201	2.31	.11	----
Sequence Errors	0.064	0.184	0.35	.71	----
Success Criterion	0.744	0.162	4.59	.05	.07

Amplitude Task

Variable	Numerator MS	Error MS	F	p <	ω^2
Time	0.064	0.049	1.30	.28	----
Repeats	4.747	0.452	10.50	.01	.17
Control Setting Errors	1.480	0.354	4.18	.05	.04
Sequence Errors	0.463	0.185	2.52	.09	----
Success Criterion	0.711	0.239	2.97	.06	----

Table 5 (Continued)

Part II : Univariate tests with 2, 87 df.

Frequency Task

Variable	Numerator MS	Error MS	F	$p <$	ω^2
Time	0.049	0.046	1.06	.35	----
Repeats	3.208	0.240	13.36	.01	.22
Control Setting Errors	0.099	0.382	0.26	.78	----
Sequence Errors	0.097	0.077	1.25	.29	----
Success Criterion	0.211	0.253	0.83	.44	----

Overall Tasks

Variable	Numerator MS	Error MS	F	$p <$	ω^2
Time	0.015	0.026	0.57	.57	----
Repeats	24.575	1.387	17.71	.01	.27
Control Setting Errors	1.243	0.610	2.03	.14	----
Sequence Errors	0.951	0.494	1.92	.16	----
Success Criteria	0.681	0.122	5.58	.01	.09

General Effects of Presentation Method Factor

While the foregoing results reveal some reasonably consistent patterns of differences with respect to task performance under varying instructional presentation methods, they do not address all of the possible contrasts. Accordingly, the following sections summarize all previously unreported comparisons of the presentation methods in which significant differences (i.e., $p < .05$ in all cases) were found based on the application of Tukey's post-hoc analysis procedure to the ANOVA results.

Time-to-Completion

For this measure, results showed that, on the average: (1) subjects using the text-audio-graphics method completed the setup, probe, and overall tasks faster than subjects who used the text-only and audio-only methods; (2) subjects using the audio-graphics method completed the setup and overall tasks faster than subjects using the text-only, audio-only, and text-audio methods; and (3) subjects using the text-graphics method completed the setup task faster than subjects using methods that excluded graphics, and also completed tasks on an overall basis faster than subjects using the text-only method.

Repeats

A comparison of mean values for this measure showed: (1) subjects using the text-only method repeated more steps on the separate and overall tasks than subjects using the four methods that included auditory instructions (i.e., audio-only, text-audio, audio-graphics and text-audio-graphics); (2) subjects using the text-only method repeated more steps than subjects using the text-graphics method on the setup, probe, and overall tasks; (3) subjects using the audio-only and text-audio methods repeated more steps on the setup, probe, and overall tasks than subjects using the audio-graphics method, and, similarly, repeated more steps on the setup and overall tasks than subjects using the text-audio-graphics method.

Control Setting Errors

This analysis showed that subjects who used the text-only method made more control setting errors on the setup task than subjects who used the audio-graphics method. In addition, it was found that subjects using the text-graphics method made more control setting errors on the amplitude task than subjects using the text-only method.

Sequence Errors

For this measure the procedure showed that subjects using the three methods that excluded graphics made more sequence errors on the setup task than subjects using the text-audio-graphics method. More sequence errors were also committed by subjects who used the text-only method on the setup task than by subjects who used the text-graphics and audio-graphics methods. Further, the results showed that subjects who used the text-only and audio-only methods made more sequence errors on the tasks as a whole than subjects who used the text-audio-graphics method.

Success Criterion

This analysis showed that a larger proportion of subjects who used the text-only method failed to reach the criterion for successful performance on the setup task than subjects who used the text-audio-graphics method.

Questionnaire Data

Differences between the subject groups and presentation methods were thus examined to determine their effects on task performance. These same factors were included in analyses of the subjects' mean ratings of the items in the user evaluation questionnaire.[7] Specifically, a 2 x 6 between-subjects MANOVA, the results of which are summarized in Table 6, was used to analyze four categories of questionnaire responses. The first category was based on the mean of ratings assigned to items 1 through 25--termed "Physical Features"; the second, on the mean of ratings assigned to items 26 through 36--termed "User Compatibility Features"; the third, on the mean of ratings assigned to items 37 through 40--termed "User Acceptance"; and the fourth, a discrete nominal scale derived from positive, negative, or no responses provided in the last section of the questionnaire--termed "Comments."

Table 6

MANOVA Results for User Evaluation Questionnaire Data

Part I : Multivariate tests with 20, 672 degrees of freedom (df).

Unit of Analysis	TraceV	F	p <
Group x Method	0.126	1.09	.35
Group Effect	0.046	1.97	.11
Method Effect	0.231	2.06	.01

Part II : Univariate tests with 5, 168 df. [a]

Effect of Presentation Method

Variable	Numerator MS	Error MS	F	p <
Physical Features	0.980	0.352	2.78	.05
User Compatibility	1.627	0.376	4.33	.01
User Acceptance	1.187	0.410	2.90	.05
Comments	0.307	0.417	0.73	.60

[a] Univariate results are not listed for the subject group by presentation method interaction or for the subject group variable because their associated multivariate F-ratios were nonsignificant (see Part I above).

[7] Responses of "Can't Evaluate" to questionnaire items were excluded from computation of mean rating values in all cases.

Inspection of Table 6, Part I, shows a statistically significant F-ratio for the main effect of presentation method in relation to the four categories of questionnaire responses, but shows nonsignificant F-ratios for the main effect of subject group and the group by method interaction. Based on these findings, it is appropriate to examine univariate results for the presentation method factor to identify the specific categories of questionnaire responses for which differences were found.

The latter results, which are summarized in Table 6, Part II, show significant F-ratios for all but the "Comments" variable. Using Tukey's post-hoc analysis procedure (with $p < .05$ in all cases), it was found that the mean ratings assigned to questionnaire items dealing with physical features and user acceptance considerations were higher for subjects who used the text-audio-graphics method (4.40 and 4.44, respectively) than for subjects who used the text-only method (3.94 and 3.90, respectively). In regard to user compatibility, the Tukey procedure showed higher mean ratings for subjects who used the audio-graphics and text-audio-graphics methods (4.33 and 4.37, respectively) than for subjects who used the text-only method (3.78); and further, that the mean rating of subjects who used the text-audio-graphics method was also larger than the 3.88 mean rating of subjects who used the text-graphics method. All other pairings did not differ significantly.

Videotaped Performances

The final basis for assessing the two independent variables used in this study involved reviewing and analyzing task performances that had been recorded on videotape for 36 subjects. Particular attention was given in these analyses to identifying any general pattern(s) of differences in the subjects' approaches to performing the tasks as a function of the grouping and presentation method factors. Comparisons of recruit and BE/E subjects' videotaped performances within the same presentation mode showed few, if any, discernible differences in the subjects' behavior when receiving the information presented in the task steps, and, similarly, when actually performing the tasks. Discernible behavior patterns were noted, however, when performances were compared among the various presentation methods. The general patterns of behavior noted in this context are summarized briefly below.

Subjects assigned to the text-only and text-graphics methods typically read each task step in its entirety before shifting their attention to the oscilloscope and related support equipment. Once this shift was made, subjects then proceeded to scan the equipment to find the particular control, switch, dial, etc., described in the task step, often glancing back to the text on the computer screen for confirmation that they had, indeed, located the correct component. In many cases, however, such confirmation was not possible because the text had already disappeared from the computer screen. As a result, subjects using these two methods made frequent use of the "REPEAT" key, particularly during the setup and probe calibration tasks, but less so during the amplitude and frequency measurement tasks.

A similar strategy was noted among subjects assigned to the text-audio, audio-graphics, and text-audio-graphics methods during their performance of the first 5 to 10 steps of the setup task. Shortly thereafter the nature of the subjects' interaction with the instructional material changed. They began directing their attention to the oscilloscope first, while listening to the instructions presented aurally, occasionally referring back to the text and/or graphics information for confirmation of specific details (e.g., discrete settings for the Volts/CM or Time/CM controls, or the location of particular controls). Moreover, because of the relatively slow rate at which audio instructions were presented,

subjects who used these methods had an opportunity to refer back to the text and/or graphics information before it disappeared from the computer screen. This pattern possibly accounted for the smaller number of task steps repeated by subjects who used these methods relative to subjects who used the text-only and text-graphics methods.

The performance strategy used by subjects assigned to the audio-only method was characterized by their attending directly to the oscilloscope from virtually the very first task step presented. In general, subjects who used this method limited their use of the repeat key to the more lengthy steps, or to cases where they could not readily locate the component(s) specified in the audio instructions.

With respect to the use of pictorial information, subjects who used the three methods that included graphics paid close attention to the "flashing arrows" presented during the first two tasks, but much less so on subsequent tasks. Subjects assigned to these methods would, on occasion, repeat a task step solely for the purpose of studying the outline drawing, but this activity also declined steadily over time.

DISCUSSION

The significant differences found for the prior training/experience and presentation method factors used in this study indicate that each impacted the efficiency and effectiveness with which subjects performed the four oscilloscope operator tasks. Moreover, the interpretation of the effects attributable to these factors, discussed separately in the following sections, is direct and straightforward because none of the interactions between them reached conventional levels of statistical significance.

Prior Training/Experience

On an overall basis the results showed that subjects in the BE/E group completed the tasks faster, repeated fewer task steps, made fewer control setting errors, and had higher success in meeting the criteria for acceptable performance than subjects in the recruit group. These findings not only support the first experimental hypothesis but also are in accord with some of the findings reported in studies described earlier (Brown, 1964; Goff et al., 1969), and, more recently, those reported by Kieras, Tibbits, and Bovair (1984).

It is interesting to note that the four types of performance measures on which the two groups differed for the tasks as a whole were not always those that differentiated the groups on the tasks individually. That is, only the time-to-completion and criterion measures differed significantly between groups on the setup and frequency measurement tasks, respectively. Several factors may explain these findings. With respect to the setup task, all subjects in both groups reported that they had no prior experience in operating the particular model of oscilloscope used in this study; thus, a learning effect probably attenuated group differences for all measures except time-to-completion. The fact that the BE/E subjects completed this task faster than the recruit subjects does suggest, however, that their familiarity with the types of controls and actions required to set up an oscilloscope appears to have generalized to the equipment used in this study.

A plausible explanation for the lack of group differences on four of the measures used to assess performance on the frequency task is that the subjects were required to use a smaller number of oscilloscope controls. That is, while subjects received instructions for manipulating 33 discrete controls in the setup task, only 5 controls were referenced in the instructions for the frequency task. Moreover, each of these 5 controls had been used at

least once in performing tasks given earlier in the sequence. It is reasonable to assume, therefore, that a learning effect may have minimized group differences on this task for all measures except the success criterion. The group difference on the latter measure can be explained largely by the BE/E subjects' greater familiarity with the processes involved in measuring and computing frequency values.

Graphics Versus Non-graphics Methods

Results from performance comparisons of subjects who used graphics methods with subjects who used non-graphics methods were generally consistent with the second experimental hypothesis. The overall measures showed that subjects assigned to the former methods completed the tasks faster, repeated fewer steps, and made fewer sequence errors than subjects assigned to the three methods that excluded graphics. It is important to note, however, that the combination of graphics with text and/or audio appears to have had its most pronounced effect on the subjects' performance early in the task sequence. That is, significant differences were found between these methods on all measures for the setup task; whereas only the time and repeat measures differed between these methods on the probe and amplitude tasks. No differences were found between these methods on the frequency task.

A possible explanation for these findings in the case of the probe and amplitude tasks is that while the graphics may have reduced the time subjects spent in searching for particular controls or in repeating task steps, they appeared to have had little, if any, effect on the accuracy of the subjects' performance (i.e., as reflected by control setting error, sequence error, and criterion measures). The lack of differences between these methods when comparing the subjects' performance on the frequency task can be explained for much the same reason offered previously. That is, it is presumed that all subjects had become sufficiently familiar with the types of controls and actions used in this task to reduce the effectiveness of graphics. This effect was also noted in the review of the videotaped performances wherein the subjects' reliance on graphics information declined steadily over time.

These findings regarding the diminishing effectiveness of graphics to procedural instructions when performing similar job tasks are not limited to the present study. For example, Smillie and Clelland (1986) reported an essentially inverse relationship between the preferences of Navy fire control technicians for using highly pictorial JPAs and the frequency of performing job tasks supported by those JPAs. That is, the technicians they interviewed expressed a preference for using JPAs to support the performance of tasks that had long intervals of time between them, but preferred not to use JPAs on tasks performed routinely.

The lack of any consistent performance differences between subjects who used the graphics and non-graphics methods across each of the tasks sampled in this study does conflict, however, with the findings reported by Booher (1975). It will be recalled that subjects in that study who received instructions through predominantly pictorial, related- or redundant-print formats performed a series of tasks consistently faster and with greater accuracy than subjects using four other methods. A plausible reason for this discrepancy is that there was no commonality either among the three types of simulated job tasks that Booher sampled or among the eight discrete problems included under each task type. Thus, in contrast to the present study, Booher's subjects were faced with an essentially novel situation on each of the 24 problems, thereby affording little opportunity for familiarization and/or transfer of learning to occur during the test session.

Audio Versus Non-audio Methods

Among the more interesting findings obtained in this study were those that led to rejection of the third and fourth experimental hypotheses. Contrary to the third hypothesis, results showed that subjects assigned to the text-only method repeated more steps on the separate and overall tasks and were less successful in meeting the criterion for acceptable performance on the setup task than subjects who used the audio-only and text-audio methods. Similar contradictory findings were obtained for the fourth hypothesis; subjects assigned to the text-graphics method repeated more steps on the separate and overall tasks, made more control setting errors on the amplitude task, and had higher failure rates on the probe and overall tasks than subjects who used the audio-graphics and text-audio-graphics methods.

Taken together, these findings suggest that the task performance of subjects assigned to the methods that included audio instructions was generally more efficient (i.e., fewer repeated steps), and in some cases more effective (i.e., fewer errors and lower failure rates) than that of subjects assigned to methods that excluded audio instructions. Once again, these findings are consistent with those from earlier studies.

Results from applied research by Henneman (1952) and his associates (e.g, Henneman, Lewis & Matthews, 1953; Henneman & Matthews, 1954; Holland & Lee, 1954), showed, for example, that when subjects were engaged in highly attention-demanding tasks, messages presented aurally were more accurately received and interfered less with the performance of simultaneous motor tasks than identical messages presented visually. Evidence for the superiority of aural over visual messages when subjects performed simultaneous motor or information processing tasks was also obtained in applied research conducted by Chapanis (1973) and his associates (e.g., Chapanis, Ochsman, Parrish, & Weeks, 1972; Ochsman & Chapanis, 1974). A relatively straightforward explanation for these findings was offered in the latter study. It stated that:

> Subjects in the hard-copy modes tend to concentrate more on their communication task, i.e., on sending or receiving. Subjects who communicate by speaking find it easier to conduct other activities simultaneously regardless of whether they are speaking or listening to spoken messages. (Ochsman & Chapanis, 1974, p. 614)

Findings from more basic research studies have also repeatedly shown that memory traces laid down during the presentation of visual stimuli are less persistent and more vulnerable to interference than traces from the same information presented aurally (e.g., Broadbent, 1956; Craik, 1969; Laughery & Fell, 1969; Margrain, 1967; Mowbray, 1952; Murdock, 1968; Neisser, 1967; Sperling, 1967; Wickelgren, 1965). Thus, in the present study, the consistently higher number of steps repeated by subjects who used the text-only and text-graphics methods compared with subjects whose methods included audio instructions would appear to be in general agreement with the findings from the studies cited above.

Another possible explanation for these findings was noted after review of the videotaped performances of subjects assigned to the text-only and text-graphics methods. Specifically, it was noted that the text often disappeared from the computer display before the subjects could go back to re-read it. As a result, the instructions presented in these methods lacked referability; Goldstein (1940) reported that referability was a critical factor determining the relative effectiveness of text and audio presentations.

The lack of referability of information presented in the text-only and text-graphics methods notwithstanding, it is also possible that the generally poorer performance of subjects who used the non-audio methods might be attributable to the physical distance that existed between the source of information (i.e., the microcomputer) and the work (i.e., the oscilloscope). It would be of interest, therefore, to determine if a similar pattern of performance differences would result between subjects who used the audio and non-audio methods when task instructions for the latter were presented in closer proximity to the equipment used to perform the job tasks.

User Attitudes

To a certain extent, the foregoing performance differences between subjects who used methods that combined audio instructions with graphics and those who did not were also reflected in the subjects' evaluations of those methods. Specifically, analyses of the user evaluation questionnaire data showed that subjects assigned to the audio-graphics and text-audio-graphics methods provided significantly higher (i.e., more favorable) ratings to items dealing with user compatibility than subjects assigned to the text-only and text-graphics methods. These data also showed that subjects who used the text-only method provided significantly lower ratings than did subjects who used the text-audio-graphics method on items concerned with the physical features of the hardware used in performing the tasks, as well as on those dealing with user acceptance.

No significant differences could be attributed to the various presentation methods with regard to open-ended comments provided by subjects in the final section of the questionnaire. It is interesting to note, however, that the majority of negative comments made by subjects who used the text-only and text-graphics methods indicated that more time should have been allowed for presenting the task steps. Subjects assigned to methods that included audio instructions made no such comments about the rate at which steps were presented aurally. It would appear, therefore, that the lack of referability in the textual instructions contributed to many of the negative comments made by subjects who used the text-only and text-graphics methods.

SUMMARY AND CONCLUSIONS

This study was designed to assess systematically the effects of prior task training or experience, and alternative methods for presenting instructional materials on job task performance. Results showed significant main effects for each of these factors separately; however, none of the two-way interaction effects between these factors reached conventional levels of statistical significance. The conclusions and implications derived from this study are discussed in more detail below.

It is interesting to note that prior training and experience in operating dual-trace oscilloscopes had their most pronounced effects on the outcome measures obtained for the probe and amplitude tasks; whereas only the time-to-completion and success criterion measures differed between groups on the setup and frequency tasks, respectively. One implication derived from these findings is that learning likely played an important role in moderating differences between groups on the initial and final tasks performed in the sequence. Such learning effects represent an additional source of variance that must be considered, and preferably factored-out in future research efforts concerned with assessing job performance.

Results from the test of the second experimental hypothesis are generally in accord with the predictions of Paivio's (1971, 1978) dual-coding theory. By conveying information through both verbal and image codes, subjects were provided with complementary processing systems, thereby enabling them to alternate between the two to obtain the information needed to perform the job tasks. Thus, each system could serve as an alternative representation of the information should there be any ambiguity (i.e., the graphics appeared to serve as a reference point for the instructions presented in text and/or audio form, while the latter appeared to serve as a focusing agent for the information presented in graphics form).

It is important to note, however, that the combination of verbal and image codes had its greatest effect on the performance of tasks administered early in the sequence, when subjects were learning the location and function of particular oscilloscope controls specified in the instructions. One of the implications of these findings is that, once learning has occurred, the effect of combined verbal and image code presentations will no longer be observed. This suggests a refinement to the dual-coding theory in that the maximum effect of combined presentations will be during the initial learning of task behaviors rather than during continuous performance of those behaviors.

In the present study, subjects who used methods that included audio instructions generally performed better. It may, under most conditions, be most efficient to present job task instructions via audio. This conclusion is supported by both basic and applied research studies that have repeatedly demonstrated that information presented aurally persists longer in short-term memory and is less vulnerable to interference than visually presented information. It is worth mentioning that these findings conflict with the empirical evidence interpreted in support of the information processing and communication theories discussed in the second section of this report (e.g., Hsia, 1977; Paivio, 1978; Van Mondfrans & Travers, 1964). Probably the most reasonable explanation for the apparent discrepancy between these findings is that the latter studies placed a premium on the subjects' ability to recall or recognize the stimulus material presented; whereas in the present study subjects were required to perform some action(s) based on the stimulus material presented.

For the types of job performance tasks and experience levels sampled, results showed that the performance of subjects who used the audio-graphics and text-audio-graphics methods was generally more efficient and effective than that of subjects who used the other presentation conditions. Additionally, the responses to questionnaire items by subjects who used these methods were generally more favorable with respect to the physical features of the hardware, user compatibility, and user acceptance.

RECOMMENDATIONS FOR FUTURE RESEARCH

The empirical evidence suggests the presence of learning effects across the series of consecutively administered job tasks. These effects tended to minimize differences between groups for both the prior training and experience variable and the graphics versus non-graphics comparisons. Such findings suggest that further research in this area is justified. Further study is also warranted to determine whether the generally superior performance of subjects who used the audio-graphics and text-audio-graphics methods would generalize to other job situations in which the supporting information was not in the form of highly proceduralized, step-by-step instructions. An example of the foregoing is troubleshooting activities that often involve circuit or signal tracing using schematic diagrams, logic trees, or "narrative" descriptions of circuit functions and their interrelationships.

Specific research recommendations for improving the design and methodology of related future studies are summarized below:

1. To control for learning effects when performing job tasks with unfamiliar equipment, all subjects should demonstrate mastery (or the lack of it) with regard to the location and function of controls on the equipment to be used in the test situation.

2. The job tasks selected for testing should be relatively independent of one another, and of comparable difficulty level, to enable the use of a counterbalanced task presentation order.

3. The task instructions in the text-only and text-graphics methods should be presented in closer proximity to the equipment used to perform the job tasks. This change might produce results that are more consistent with the third and fourth hypotheses tested in this study.

4. Discrete measures should be obtained on each procedural step to enable a comparative assessment of differences attributable to short versus lengthy procedural instructions.

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APPENDIX A

BACKGROUND INFORMATION FORM

AN/USM-281 OSCILLOSCOPE OPERATOR TEST:

BACKGROUND INFORMATION FORM

SUBJECT NUMBER:_____ CLASSIFICATION: RECRUIT___ BE/E STUDENT___

TEST DATE: _________ PRESENTATION MODE: ______________________

1. How old are you? ____

2. What is the highest level of education you completed before entering the Navy?

____

3. Is English your native language? Yes_____ No_____. If no, specify native language.

____

4. Do you have any vision and/or hearing problems that you are aware of at the present time? No_____ Yes_____. If yes, specify type and extent of problem(s).

____

____

5. How long have you been in the Navy?__________________________

6. What Navy rating do you intend to have at the end of your current enlistment period (e.g., electronics technician, fire control technician, sonar technician)?

____

____

7. Did you have any prior military service before entering the Navy? No _____ Yes _____. (If yes, specify which service and any occupational specialty(ies) held.)

____

____

8. Before entering the Navy, did you have any formal schooling or training in the areas of electricity or electronics? No _____ Yes_____. (If yes, specify the nature and type of schooling/training received; e.g., high school shop class(es), vocational/trade school, factory-sponsored training, etc.)

____

____

____

9. Before entering the Navy, did you have any work experience in the area of electricity or electronics? No _____ Yes_____. (If yes, specify the nature and type of work experience received; e.g., part-time job in TV repair shop, apprentice electrician or helper, etc.)

____

____

____

10. Have you ever operated an oscilloscope before? No_____ Yes_____. (If yes, specify when, where, and how much oscilloscope operation experience was accumulated and the type(s) of oscilloscopes used.)

____

____

____

APPENDIX B

STANDARDIZED CONTROL SETTINGS FOR AN/USM-281 OSCILLOSCOPE AND RELATED SUPPORT EQUIPMENT

AN/USM-281 OSCILLOSCOPE OPERATOR TEST

SPECIFICATION SHEET #2

The following describes the procedure for undercompensating the divider probe and lists required control settings and adjustments on the USM-281 oscilloscope before administering the PROBE CALIBRATION TASK.

PART I. Procedure for Undercompensating the Divider Probe

Position controls and switches on USM-281 oscilloscope as follows:

(a) Set CHANNEL A INPUT COUPLING switch to AC.

(b) Rotate CHANNEL A VOLT/CM control to .5 Volt/CM.

(c) Rotate MAIN TIME/CM control to .5 MSEC.

Perform the following adjustments to the divider probe:

(a) Remove probe body and tip assembly and attach banana plug adapter to threaded end of probe body.

(b) Loosen locking sleeve on divider probe by turning it counterclockwise one full turn.

(c) Connect BNC coupling on divider probe to CHANNEL A INPUT connector post.

(d) Attach probe ground lead (alligator clip) to CALIBRATOR GND jack; insert banana plug in CALIBRATOR 10V jack.

(e) Adjust FOCUS and CHANNEL A POSITION controls as necessary to present a "sharp" image, centered on the the oscilloscope display screen.

(f) Rotate probe body clockwise until leading edge of upper square waveform and leading edge of lower square waveform "curve" toward the horizontal graticule line at the center of the oscilloscope display.

(g) Tighten locking sleeve on divider probe by turning it clockwise until finger-tight; ensure that undercompensated waveform is still present on oscilloscope display after after locking sleeve has been tightened.

(h) Remove BNC coupling on divider probe from CHANNEL A INPUT connector post, probe ground from CALIBRATOR GND jack, and banana plug from CALIBRATOR 10V jack.

(i) Remove banana plug adapter from end of probe body and reinstall "original" probe body and tip assembly.

PART II. Pre-Test Settings for USM-281 Oscilloscope

When the divider probe has been undercompensated, ensure that oscilloscope switch and control settings are positioned as follows:

OSCILLOSCOPE CONTROLS/SWITCHES	PRE-TEST SETTINGS	CORRESPONDING STEP NUMBER
INTENSITY	Center of rotation	1
FOCUS	Center of rotation	2
POWER	OFF	3
HORIZONTAL POSITION	Center of rotation	4
HORIZONTAL MAGNIFIER	X1	5
HORIZONTAL DISPLAY	INT	6
HORIZONTAL AC-DC SWITCH	AC	7
MAIN VERNIER	Clockwise to locked position	8
DELAYED VERNIER	Clockwise to locked position	9
SWEEP DISPLAY	Fully clockwise	10
MAIN TIME/CM	1 USEC	11
DELAYED TIME/CM	OFF	12
MAIN TRIGGER LEVEL	Mid-position	13
DELAYED TRIGGER LEVEL	Mid-position	14
SWEEP MODE	AUTO	15
MAIN TRIGGER SOURCE	INT	16
DELAYED TRIGGER SOURCE	AUTO	17
MAIN SLOPE	Plus (+) sign	18
DELAYED SLOPE	Plus (+) sign	19
MAIN TRIGGER COUPLING	AC	20
DELAYED TRIGGER COUPLING	AC	21
CHANNEL A POSITION	Center of rotation	22
CHANNEL B POSITION	Center of rotation	23
VERTICAL DISPLAY	"A"	24
CHANNEL A POLARITY	Plus (+) sign UP	25
CHANNEL B POLARITY	Plus (+) sign UP	26
CHANNEL A VERNIER	Clockwise to locked position	27
CHANNEL B VERNIER	Clockwise to locked position	28
CHANNEL A VOLT/CM	5 Volt/CM	29
CHANNEL B VOLT/CM	5 Volt/CM	30
VERTICAL MAGNIFIER	X1	31
CHANNEL A INPUT COUPLING	GND	32
CHANNEL B INPUT COUPLING	AC	33

APPENDIX C

EXAMPLE OF A PERFORMANCE OBSERVATION FORM

PERFORMANCE OBSERVATION FORM #1

PRELIMINARY SET-UP AND ADJUSTMENT TASK

Examinee Number: ______ Classification: Recruit _____ BE/E _____

Test Date: ____________ Presentation Mode: ______________________

Instructions: Score one point for each step performed correctly and one point for correct sequencing of each step. Score 0 for an incorrect performance or sequencing of steps; indicate specific error(s) made under the column headed "Comments."

Step	Control-Operation	Correct Setting	Correct Sequence	Comments
1	INTENSITY--12 o'clock			
2	FOCUS--12 o'clock			
3	POWER--OFF			
4	HORIZONTAL POS.--12 o'clock			
5	HORIZONTAL MAG.--X1			
6	HORIZONTAL DISPLAY--INT			
7	HORIZONTAL AC-DC--AC			
8	MAIN VERNIER--fully CW			
9	DELAYED VERNIER--fully CW			
10	SWEEP DISPLAY--fully CCW			
11	MAIN TIME/CM--1 USEC			
12	DELAYED TIME/CM--OFF			
13	MAIN TRIG. LEVEL--mid pos.			
14	DEL. TRIG. LEVEL--mid pos.			
15	SWEEP MODE--AUTO			
16	MAIN TRIGGER SOURCE--INT			
17	DELAYED TRIG. SOURCE--AUTO			

Step	Control-Operation	Correct Setting	Correct Sequence	Comments
18	MAIN SLOPE--(+) sign			
19	DELAYED SLOPE--(+) sign			
20	MAIN TRIGGER COUPLING--AC			
21	DELAYED TRIG. COUPLING--AC			
22	CHANNEL A POS.--12 o'clock			
23	CHANNEL B POS.--12 o'clock			
24	VERTICAL DISPLAY--"A"			
25	CHANNEL A POLARITY--(+) UP			
26	CHANNEL B POLARITY--(+) UP			
27	CHANNEL A VERNIER--fully CW			
28	CHANNEL B VERNIER--fully CW			
29	CHANNEL A VOLT/CM--5 volt/cm			
30	CHANNEL B VOLT/CM--5 volt/cm			
31	VERTICAL MAGNIFIER--X1			
32	CHAN. A INPUT COUPLING--GND			
33	CHAN. B INPUT COUPLING--AC			

APPENDIX D

EXAMINEE WORKSHEET FORM

EXAMINEE WORKSHEET

Examinee Number: ________ Classification: Recruit____ BE/E ____

Test Date: ____________ Presentation Mode: ____________________

AMPLITUDE MEASUREMENT CALCULATIONS

Step 66. Number of centimeters counted = ______________

Step 67. CHANNEL A VOLTS/CM setting x 10 = ______________

Step 68. Result Step 66 x Result Step 67 = ______________

Step 69. $\dfrac{\text{Result Step 68}}{\text{VERTICAL MAGNIFIER setting}}$ = ______________

FREQUENCY MEASUREMENT CALCULATIONS

Step 81. Number of centimeters counted = ______________

Step 82. Result Step 81 x MAIN TIME/CM setting = ______________

Step 83. Result Step 82 x 0.000001 = ______________

Step 84. $\dfrac{\text{Result Step 83}}{\text{HORIZONTAL MAGNIFIER setting}}$ = ______________

Step 85. $\dfrac{1}{\text{Result Step 84}}$ = ______________

APPENDIX E

USER EVALUATION QUESTIONNAIRE FORM

USER EVALUATION QUESTIONNAIRE

Examinee Number: ______ Classification: Recruit _____ BE/E _____

Test Date: ____________ Presentation Mode: ______________________

Directions:

You are asked to evaluate the items on this questionnaire using the 5-point scale appearing to the right of each item. Rate each item by placing an "X" in the appropriate column. Because the same questionnaire will be given to all examinees, there may be some items you cannot evaluate due to the particular method and equipment you used for receiving the performance steps. In those cases, please place an "X" in the column headed: "Can't Evaluate."

SECTION 1: PHYSICAL FEATURES

Items 1 through 25 concern the following physical features of the equipments and methods used for performing the oscilloscope operator tasks:

--The layout of equipment on the workbench,

--The two push-button "Command" keys located on the computer keyboard,

--The computer display screen and audio equipment used to present the performance steps.

SCALE VALUES

ITEMS	UNSATIS-FACTORY	MARGINAL	SATISFACTORY	HIGHLY SATISFACTORY	OUTSTANDING	CAN'T EVALUATE
1. Physical distance between you and the equipment(s) used to present the performance steps (e.g., the computer display, keyboard, and loudspeaker).						
2. Physical distance between the equipment(s) used to present the performance steps and the equipment required to perform the tasks (i.e., the oscilloscope, divider probe, and black box).						

SCALE VALUES

ITEMS	UNSATIS-FACTORY	MARGINAL	SATISFACTORY	HIGHLY SATISFACTORY	OUTSTANDING	CAN'T EVALUATE
3. Physical placement of equipments on the workbench. (I.E., Was the equipment arranged in a useable and functional order?)						
4. Impression of overall layout of equipments on the workbench.						
5. Adequacy of identification labels for switches and controls on the equipment required to perform the tasks.						
6. Location of ADVANCE and REPEAT keys on the computer keyboard.						
7. Spacing of ADVANCE and REPEAT keys.						
8. Ease of operating ADVANCE and REPEAT keys.						
9. Indication(s) that ADVANCE and REPEAT keys had been activated.						
10. Reliability of the ADVANCE and REPEAT keys. (I.E., Did the computer respond appropriately to the keys you pressed?)						
11. Overall adequacy of ADVANCE and REPEAT keys.						
12. Glare resistance of the computer display screen.						

ITEMS	SCALE VALUES: UNSATIS-FACTORY	MARGINAL	SATISFACTORY	HIGHLY SATISFACTORY	OUTSTANDING	CAN'T EVALUATE
13. Legibility of printed performance steps. (I.E., Were letters, words, and numbers easy to read?)						
14. Format/arrangement of printed steps (i.e., lack of clutter and crowding).						
15. Clearness of performance steps read aloud to you (i.e., not garbeled).						
16. Volume level of the steps read aloud to you.						
17. Size of outline drawings provided for oscilloscope, divider probe, and black box.						
18. Interpretability of outline drawings (i.e., lack of clutter and crowding).						
19. Format/arrangement of outline drawings. (I.E., Were they presented in a logical and understandable way?)						
20. Resolution/clarity of outline drawings.						
21. Brightness of outline drawings.						
22. Contrast between outline drawings and background on the computer display screen.						

SCALE VALUES

ITEMS	UNSATIS-FACTORY	MARGINAL	SATISFACTORY	HIGHLY SATISFACTORY	OUTSTANDING	CAN'T EVALUATE
23. Adequacy of detail provided on outline drawings.						
24. Adequacy of outline drawings for supplementing printed and/or spoken performance steps.						
25. Adequacy of "flashing arrow" to highlight switches and controls on the outline drawings.						

SECTION 2: PRESENTATION METHODS

Items 26 through 40 concern the following aspects of the methods used for presenting the oscilloscope operator task instructions:

--Organization, sequencing, and pacing of the performance steps,

--Clarity/completeness of information contained in the performance steps,

--Ease of performing actions specified in the performance steps,

--Overall impression of the method you used for receiving the performance steps.

To avoid repetition in the wording of the items contained in this section, please begin each with the phrase:

BASED ON THE METHOD YOU USED FOR RECEIVING THE PERFORMANCE STEPS, HOW WOULD YOU RATE IT IN TERMS OF...

	SCALE VALUES					
ITEMS	UNSATIS-FACTORY	MARGINAL	SATISFACTORY	HIGHLY SATISFACTORY	OUTSTANDING	CAN'T EVALUATE
26. Completeness of information provided.						
27. Ordering of steps in the task sequences						
28. Clarity of the wording in the performance steps. (I.E., Did each step describe exactly what action(s) to perform?)						
29. Conciseness of the wording in the performance steps. (I.E., Did each step describe the action(s) to perform using a minimum number of words?)						

BASED ON THE METHOD YOU USED FOR RECEIVING THE PERFORMANCE STEPS, HOW WOULD YOU RATE IT IN TERMS OF...

SCALE VALUES

ITEMS	UNSATIS-FACTORY	MARGINAL	SATISFACTORY	HIGHLY SATISFACTORY	OUTSTANDING	CAN'T EVALUATE
30. Rate at which the performance steps were presented.						
31. Ease of using the information to locate controls and switches on the oscilloscope, divider probe, and black box quickly and accurately.						
32. Ease of using the information to perform the action(s) specified in the steps.						
33. Minimizing physical fatigue (e.g., tired eyes, backache, etc.).						
34. Minimizing mental fatigue (e.g., being overloaded with information, confused, frustrated, etc.).						
35. Minimizing the requirement to repeat the same performance step(s).						
36. Minimizing the time and effort required to perform the oscilloscope operator tasks.						
37. Your level of confidence in performing the oscilloscope operator tasks.						

BASED ON THE METHOD YOU USED FOR RECEIVING THE PERFORMANCE STEPS, HOW WOULD YOU RATE IT IN TERMS OF...

SCALE VALUES

ITEMS	UNSATIS-FACTORY	MARGINAL	SATISFACTORY	HIGHLY SATISFACTORY	OUTSTANDING	CAN'T EVALUATE
38. Your level of confidence in using this method to perform other types of job tasks.						
39. Its adequacy and acceptability for presenting information needed to perform job tasks.						
40. Its overall adequacy and acceptability.						

SECTION 3: GENERAL REACTIONS AND COMMENTS

This section provides spaces for making any comments, complaints, suggestions, etc. you have regarding the method you used to receive instructions for the oscilloscope operator tasks.

____

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This concludes the user evaluation questionnaire. Your assistance in providing this information is appreciated.

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